Interim Report

Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects

Estes Park, Colorado
September 19-23, 1999

Edited by

Thomas J. O'Shea
U.S. Geological Survey
Midcontinent Ecological Science Center
4512 McMurry Avenue
Fort Collins, CO 80525-3400

Michael A. Bogan
U.S. Geological Survey
Midcontinent Ecological Science Center
Aridlands Field Station
Museum of Southwestern Biology
University of New Mexico
Albuquerque, NM 87131

Workshop Sponsors: U.S. Geological Survey, National Fish and Wildlife Foundation, Bat Conservation International, Bureau of Land Management, and U.S. Forest Service.

Steering Committee: Co-Chairs: Thomas J. O'Shea, Michael A. Bogan, U.S. Geological Survey; Mary Kay Clark, North Carolina State Museum of Natural Science; Laura E. Ellison, U.S. Geological Survey; Joseph Kath, Illinois Department of Natural Resources, Division of Natural Heritage; Thomas H. Kunz, Boston University; Kirk Navo, Colorado Division of Wildlife; William E. Rainey, University of California, Berkeley; Merlin D. Tuttle, Bat Conservation International.

Preferred Method of Citation: "O'Shea, T. J. and M. A. Bogan (editors). 2000. Interim Report of the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. [On-line Interim Report]. U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, Colorado, 124 pp. Available: http://www.mesc.usgs.gov/BPD/ireport.htm"

Table of Contents

I. Introduction

Bats are inconspicuous but important components of healthy ecosystems in the United States, and are among the most diverse groups of mammals. They are of major regional economic importance as consumers of forest and agricultural insect pests, and some bat species in the U.S. and Territories play significant ecosystem roles as pollinators and seed dispersers. However, in comparison with other small mammals, bats have low reproductive rates (1-2 young per year) and long life spans (some live over 30 years) and require high survival rates for populations to persist. In addition, some species have very narrow roosting and habitat requirements that result in colonial aggregations of large segments of the total population at a very few sites. Populations are consequently very susceptible to elevated mortality or depressed recruitment. Disturbance to roost sites, vandalism, habitat change, and contaminants have contributed to declines in populations of many species. Natural catastrophes such as hurricanes, typhoons, and flooding have also played a role in bat declines (particularly when populations have previously been forced into marginal roosts or reduced in numbers by other causes). Some Pacific Island fruit bat populations have been decimated in part because of their use as a delicacy in the human diet. Twenty-eight taxa (23 species and five subspecies or Pacific Island populations) of bats were included in the 1994 U.S. Fish and Wildlife Service Federal Register Notice of Review of Animal Candidates for Listing under the Endangered Species Act. Twenty-six of these are now considered “Species of Concern” by the U.S. Fish and Wildlife Service (primarily former Category 2 Candidate Species since a change in policy in 1996 which no longer utilizes the Category 2 classification). Many of these taxa were considered candidates for listing in part because of a lack of available information on population status. This is an extraordinary number of Species of Concern within this group of mammals (there are only about 45 species of bats in the U.S. exclusive of the Territories).

Declining bat populations have thus become a concern on the part of the public and resource management agencies throughout the nation, but there are no established means for tracking future trends in bat populations at scales beyond local efforts or monitoring of endangered taxa. This makes it difficult to recognize conservation priorities for management as well as conservation successes. For most groups of bats, there is also a lack of standardized approaches for estimating numbers. This workshop was therefore convened to explore the scientific feasibility of, and develop recommendations for, monitoring bat population trends in the United States and Territories. Emphasis of the workshop was on examining issues that must be overcome in the areas of statistical design and organization, and on defining priorities that must be considered in future actions on this topic. The objectives did not include immediate organization or implementation of a bat-monitoring program.

The status of bat populations is of direct concern to resource managers nationwide, who have become increasingly concerned about maintaining populations of bat species of concern. Regional working groups consisting of bat biologists representing state agencies, non-government organizations, and federal agencies have been organized to help coordinate approaches to bat research and conservation, and population monitoring is a key element of their discussions. The U.S. Geological Survey is interested in bat population monitoring as the principal scientific research arm for Department of the Interior resource managers. Many thousands of mines and caves that provide potential habitat for cave-roosting bats occur on lands managed by the Bureau of Land Management, National Park Service, Bureau of Reclamation, and U.S. Fish and Wildlife Service. Large areas with similar habitat are also managed by the U.S. Forest Service, other federal and state agencies, as well as non-government organizations and private concerns. These lands provide foraging habitats for bats, potential watering sites, cliffs for crevice-dwelling species, and snags and other roost sites for forest-dwelling bats.

II. Objectives

Despite an increasing attention and concern for bat populations, efforts for determining bat population status and trends are highly fragmented among various agencies and organizations according to their individual interests and responsibilities. Within the U.S., most of the attention has focused on endangered species and a few cavernicolous taxa at a limited number of locations. There is no single source of information that provides detailed information or analyses on how widespread, and at what magnitude, bat population declines or recoveries may have occurred over the entire nation.

Therefore, the general objectives of this workshop were to:

1. Review what is known about the status and trends of populations of various groups of bat species in the U.S. and Territories, including descriptions of how these trends were quantified and the likely causes of declines or reversals in declines, when known.

2. Provide an overview of the current methods and challenges involved in estimating population size and trends for major ecological groupings of U.S. bat species.

3. Identify critical gaps in knowledge concerning bat population trends in the U.S. and Territories.

4. Determine, describe, and recommend scientific goals for future monitoring programs, including possible new and innovative approaches in designs needed to resolve technical challenges in estimating bat population trends.

This workshop was a science-focused, working meeting involving a limited number of invited experts. Participants represented five key disciplines: 1) experts on the life history and biology of bats in the U.S. and Territories; 2) authorities on the statistical determination of population sizes and trends in animals; 3) biologists with experience in designing and implementing bat surveys; 4) specialists in the design of national inventory and monitoring programs developed for other organisms; and 5) representatives of agencies and conservation groups with major interests in the topic. Participants were organized into teams charged with developing specific written products and scientific recommendations to be included in a final workshop report. The final report will also contain peer-reviewed scientific overview papers based on the spoken presentations, most of which were intended to illustrate the range of variation in both bat natural history and logistical/statistical challenges to estimating bat population trends. The final Workshop Report will be published in a technical report series of the U.S. Geological Survey. However, in order to facilitate the more rapid dissemination of the Working Group findings while technical papers are undergoing review and editing, we have posted this Interim Report on the World Wide Web. Extended abstracts of the technical presentations are also included.

Acknowledgments. This workshop was sponsored by the U.S. Geological Survey through the Midcontinent Ecological Science Center (MESC) and the Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, Colorado, and the Status and Trends Program Office, Reston, Virginia; Bat Conservation International, Austin, Texas; and the National Fish and Wildlife Foundation, U.S. Forest Service, and Bureau of Land Management, Washington, D.C. Steering committee members (Mary Kay Clark, Laura Ellison, Joe Kath, Tom Kunz, Lyle Lewis, Kirk Navo, Bill Rainey and Merlin Tuttle) provided valuable guidance in the planning and organizing of the content of the workshop. We thank all the participants and their respective home organizations for their attendance at the workshop and time spent in preparing and reviewing the workshop reports. Many individuals assisted with workshop logistics and administrative arrangements, but in particular we thank Michelle Banowetz, Paul Cryan, Laura Ellison, Pam Smith, and Ernest Valdez of MESC; Beverly Klein and Karen Adleman, Colorado Cooperative Fish and Wildlife Research Unit; Steve Walker and Merlin Tuttle, Bat Conservation International; Gabriella Chavarria, National Fish and Wildlife Foundation; and Mark Bosch, U.S. Forest Service. A. Lance Everette assisted in making this document available through the Internet. Finally, the editors thank the workshop participants who graciously gave their time and best efforts to help improve earlier drafts of this interim report.

III. Working Group Reports

Prior to the workshop, participants submitted lists of important unresolved issues pertinent to monitoring bat populations in the U.S. and Territories. Three main topic areas were defined, and the issues were listed within these topic areas. Participants also ranked their preferences for joining working groups corresponding to these topic areas. The topic areas were:

(A) Analytical and methodological problems in assessing bat numbers and trends, their basis, and needed research and improvements in techniques

(B) Categorizing U.S. bat species or species groups, and regions in terms of priorities for establishing population-trend monitoring programs based on conservation concerns, roosting habits, distributions, threats, and other factors

(C) Existing information and programs to monitor bat population trends: utility and coverage of current efforts, and potential expansion in scale

At Estes Park each of the main Working Groups (A-C) met following the presentations and panel discussion and identified specific issues to discuss in greatest detail, and subsequently developed recommendations and written statements on these issues. The issue statements were intended to provide: a succinct definition of the issue; a short description of what is known about the issue and what critical uncertainties surround the issue; and recommendations on how research, monitoring, or programmatic frameworks might best be designed to resolve these uncertainties. (Critical uncertainties were considered to be the facts, scientifically reliable data, research approaches, or programmatic means that need to be established in order to resolve specific issues related to monitoring bat populations in the U.S. and Territories.)

Participants were encouraged to follow a format in working group reports that included the following sections: Issue Title, Issue Description and Rationale, Means to Resolve the Critical Uncertainties Surrounding the Issue, and Suggestions Regarding Existing Monitoring and Research Programs. The "Issue Description and Rationale" section explains why the issue is important, what is generally known about the issue, what in general needs to be determined to resolve the critical uncertainties surrounding the issue, and what the consequences will be if the issue is not addressed (e.g., how it will retard progress in science and policy, what the implications are for bat populations in the U.S. and Territories). The section "Means to Resolve the Critical Uncertainties Surrounding the Issue" recommends the kinds of observations, studies, experiments, or monitoring programs that are needed. The strengths, weaknesses, and feasibility of various approaches are identified as appropriate. A final section "Suggestions Regarding Existing Monitoring and Research Programs" is included when appropriate. This section provides recommendations for improvements to ongoing efforts that attempt to address the issue of monitoring U.S. bat populations. (Not all issue statements follow this format, depending on the judgement of the participants at the time the statements were initially developed.) Literature citations are combined in a single reference list after the Working Group C report. In the weeks following the workshop, drafts of the written statements were circulated among all workshop participants for final review and comment prior to posting on the World Wide Web.

Principal Conclusions and Recommendations

A number of conclusions and recommendations regarding monitoring of U.S. bat populations emerged at the workshop as a result of the presentations, panel discussions, and working group reports. In this section, the editors have attempted to highlight major aspects of these findings under five general headings. Much greater detail on these topics is found in each working group report. This summary was circulated to each workshop participant for review and comment with the draft interim report. Conclusions and recommendations are not listed in any order of priority, because the workshop participants did not attempt to rank every issue considered. In general, the focus and objectives of this workshop (see above) emphasized providing general overviews of the state of the science in monitoring U.S. bat populations, and stressed identification of critical gaps and important directions for future research and monitoring. Excellent descriptions of techniques currently employed widely in the study of bat populations are available in the volumes edited by Kunz (1988) and Wilson et al. (1996).

(1) The Natural History of Bats Poses Many Challenges to Population Monitoring. Bats pose many logistic challenges to population monitoring. They are a very heterogenous group of

mammals in terms of natural history, and require the application of multiple approaches to monitoring. Some species are essentially solitary and roost cryptically in foliage, whereas others aggregate in the millions at predictable locations. Many others occur in a range of intermediate situations. Bats are highly mobile, almost all are nocturnal, and they generally roost in inaccessible or concealed situations. Their annual cycles can include seasonal long-distance migrations, and some species form colonies of different size, sex and age compositions at different times of the year. They are also very susceptible to disturbance, which can reduce survival (particularly in hibernation). Some colonies switch roost locations every few days or less during warm months, and basic natural history, distribution, roosting preferences and colony locations are poorly known for many species.

Despite these problems, the working group reports provide a number of recommendations aimed at improving monitoring of populations of bats in four specific categories: colonial species, over-dispersed species (i.e., foliage-, cavity-, and crevice-roosting bats), Pacific Island fruit bats, and southwestern pollinators. Monitoring of colonial species can be improved by timing surveys to coincide with periods in the annual cycle when colony size is most stable and at a seasonal peak, as for example, conducting exit counts at maternity colonies during the week prior to parturition. Guidelines for making such exit counts are provided, including using multiple observers to assess observer variation, and using standard forms for recording data and ancillary information. Bats that roost in foliage, tree cavities and rock crevices tend to roost in low densities or solitarily, and present additional challenges for monitoring. Current estimates of relative abundance of over-dispersed species come primarily from mist net and echolocation detector index measures. However, these methods have no means for estimating detectability and thus provide data of limited value for assessing abundance. Surmounting problems in estimating numbers of these bats will require improvements in methodology. The three species of Pacific Island fruit bats pose very difficult challenges to population monitoring because of patterns of dispersion, rarity, and inaccessibility. The most pressing need for monitoring populations of these fruit bats is to improve methods of estimating detectability. This might best be developed by improving abilities to capture, mark, and resight these bats. Developing artificial lures through use of sound, scent, or food-based baits and experimenting with means of inducing self-marking merits exploration, as does using controlled hunts of fruit bats to recover marked individuals (other than those protected by the U.S. Endangered Species Act [ESA]). In the interim, current methods should be continued, standardized, and include measures of logical covariates to abundance. Current monitoring of southwestern pollinators should also be continued, as methods under use are likely to reveal major trends or catastrophic changes. However, techniques for monitoring pollinators should be standardized and improved with infrared videotaping and use of additional observers.

(2) Major Improvements are Needed in Methods of Estimating Numbers of Bats. With the possible exception of certain small colonies in which individual bats can be completely counted, attempts to estimate bat population trends in the U.S. and Territories have relied heavily on use of indices at local sites. The use of indices to estimate population size and trends in animals in general is inferior to more statistically defensible methods, and can lead to incorrect inferences. New techniques must be explored and modern statistical designs applied in order to improve the

scientific basis for conclusions about future bat population trends. Although the bat research community should strive to improve scientific methods of population estimation for future applications, we agree that changes in bat abundance documented by less direct methods, when accompanied by clear-cut causes, have provided strong evidence of past declines. Bat conservation efforts are well-founded, and current monitoring approaches, although providing scientifically less rigorous information than desirable, have some merit for conservation if applied cautiously and conservatively. However, shortcomings of current methods must be fully acknowledged. The use of indices has serious flaws because most indices, including those using echolocation detectors, are affected by a host of variables other than actual trends in populations of bats. These include environmental variables, observer variables, and variables related to the bats themselves, all of which can affect counts by altering detection probabilities in complex and largely unknown ways. Furthermore, these variables may also change with time, obscuring the ability to assess and understand the true trends in bat populations. Developing uniform standards for collecting index data can be useful, but aspects of many important variables affecting detection probabilities are unknown and cannot be standardized. This weakens the reliability of index values even when controllable factors are accounted for using standardized approaches.

New research is needed to develop means to replace currently used indices, particularly if bat population monitoring objectives include detecting declines before they become catastrophic. The working group reports provide a number of recommendations for improving techniques for estimating population trend and population parameters (e.g., survival, reproduction, dispersal, and movements among strata). These include recommendations to assess the feasibility of applying new theory in mark-recapture statistics to sampling designs, to develop new marking and resighting technology (such as Passive Integrated Transponder [PIT] tags and microtaggants), to incorporate double-sampling techniques and other means to calibrate indices, and to introduce replication and multiple observers in order to incorporate estimates of variance in exit counts or other counting situations. Developing applications of new technical equipment to assist in estimating numbers is also recommended. Such equipment may include video cameras with low light recording capability, infrared video cameras (reflectance-based imagery), computer methods for counting bats in these images, and infrared cameras and other remote sensing techniques. Attempts to use infrared or other new technology and multiple observers to calibrate indices based on detection of echolocation calls should be explored for estimating abundance of over-dispersed bats.

(3) Objectives and Priorities of Bat Population Monitoring Need Careful Consideration.
Model species for population monitoring programs should be carefully selected based on specified objectives and relevant spatial scales, and monitoring should be carried out using proven methodology that provides reliable information on population trends. Poorly designed or flawed monitoring programs could lead to unreliable results at the cost of disturbance or other potential harm to bat survival. Priority-setting should consider species distributions, feeding strategies, roosting habits, population status, threats to the species, and feasibility of obtaining reliable data. Species with specialized roosting requirements and very limited numbers of suitable roosts are of high importance for monitoring for conservation of biodiversity. Species with feeding strategies of great economic or ecosystem importance may also be of high priority

for monitoring. Although most monitoring has been limited to bats that are legally classified as endangered, monitoring programs may better benefit unlisted species by providing data needed to prevent such taxa from becoming listed in the future. Species with localized distributions may be more amenable and important for monitoring than species that occur across the continent, particularly considering sampling logistics, likely smaller population sizes, and greater ability of managers to recognize specific human activities with potential to impact populations. Conversely, a monitoring program for species that roost in moderate-to-large colonies may be quite successful because of the relative ease in detecting such roosts and the fewer sites that need to be monitored.

(4) Monitoring Bat Populations on a Broad Scale Will Require Strong Commitment and Well-Planned Sampling Designs. Changes in bat populations have ramifications for agricultural and forestry segments of the U.S. economy, ecosystem function, and conservation of national biological diversity. There is a need for status information on a wide range of U.S. species, and bat population monitoring programs on a national or other broad scale are clearly desirable. However, there is no unifying mandate or legislative foundation for a national bat conservation program. Bats in the U.S. cross international and state boundaries, and models for bat conservation exist in international agreements in Europe (Agreement on the Conservation of Bats in Europe, London, 1991), the Migratory Bird Treaty Act and the Marine Mammal Protection Act in the U.S., and other conservation mandates. As in these other examples, population monitoring should be an important component of such mandates. Firmer foundations for bat conservation and monitoring are needed, including heightening public support through efforts such as a National Bat Awareness Week. Any resulting expansion in population monitoring efforts, however, must recognize the need for application of the most appropriate statistical sampling and hypothesis-testing approaches in order to provide scientifically meaningful results. This will require research on basic ecology and life history of some species of bats, breakthroughs in developing detectability functions for population estimation, and development of appropriate spatial sampling frames.

(5) Information Exchange Among Bat Specialists Should be Enhanced. Existing efforts to monitor bat populations are not well-linked. Methods and protocols may lack comparability, and the information gathered may not be used as effectively as possible in signaling the extent and magnitude of bat population problems needing conservation attention. A web-based clearinghouse should be developed to enhance information exchange about bat population monitoring. A voluntary clearinghouse could provide useful information directly, and also provide electronic links to existing sites maintained by others. As examples, information or links could include a directory of organizations and individuals, descriptions of sampling protocols, a simple metadata description of ongoing studies, a bibliography, the bat population database under development by the U.S. Geological Survey, and echolocation call libraries. Given the potential value of renewed efforts at marking bats for population studies, a web-based clearinghouse that includes information on bat marking techniques, statistical approaches to marked animal sampling designs and data analysis, pertinent bibliographic references, directories of individuals and organizations marking bats, and metadata on tagging projects would also be of value.

Working Group A. Analytical and Methodological Problems in Assessing Bat Numbers and Trends, Their Basis, and Needed Research and Improvements in Techniques

Working Group Members: Bob Berry, Mike Bogan, Anne Brooke, Tim Carter, Paul Cryan, Virginia Dalton, Ted Fleming, Jeff Gore, Michael Herder, John Hayes (Leader), Tom Kunz, Gary McCracken, Rodrigo Medellin, Alex Menzel, Mike Rabe (Rapporteur), Paul Racey, Ruth Utzurrum, Allyson Walsh, Gary Wiles, Don Wilson

This Working Group divided into four subgroups to deal with the numerous issues under consideration. The four subgroup topics were: colonial bat species, over-dispersed bats, Pacific Island fruit bats, and southwestern pollinators. In addition, many of the issues that were considered by this group were directly related to topics that emerged from the panel discussion and a seminar on mark-recapture statistical procedures. This report therefore also provides a summary of pertinent aspects of the panel discussion and seminar as a background to the subgroup reports, and a brief discussion of definitions and general monitoring requirements before presenting subgroup findings.

Panel Discussion

The Working Group acknowledged that the Monday afternoon Panel Discussion was directly relevant to the charge of the group. Panel members were: Don Wilson, moderator; David Anderson; Kenneth Burnham; Thomas Kunz; John Sauer; Allyson Walsh; and Gary C. White. Summarizing the entire discussion is beyond the scope of this report as there were many issues raised by participants and panel members. However, much of the discussion centered on the statistical reliability of current bat research and monitoring programs. In that regard, two exchanges, paraphrased below, were deemed especially relevant although unanimity of opinion on these issues varied.

Question I. A considerable amount of historical data on bat populations is available. Are these data useful or do we need to establish new monitoring designs?

Response: Most historical data are indices of population parameters and not direct measures of the parameters of interest. For example, mist net captures are indices of abundance, but do not measure abundance directly. An index is a convolution of several things, and we are almost always unable to determine what the index means in terms of the parameter. An index is a combination of: 1) true abundance (this is what we are typically interested in); 2) observer effect; 3) environmental effects; 4) animal behavior cues, i.e., cues that cause us to detect (or catch) one animal and not another. The last three effects interfere with our ability to provide the most scientifically defensible population estimates. By using an index, we assume that there is a direct, linear relationship between our index and the parameter of interest (e.g., population size). With an index, we assume that this relationship is invariant over time (which is not reasonable) and thus our index provides some kind of “relative abundance” information. Such indices may only be “numbers” rather than data that lend themselves to good science; we should not be using indices when other methods are available. We need to strive to upgrade to more robust techniques than are currently being used to monitor bat abundance.

Question II. It seems as if "robust techniques" are currently not applicable to monitoring studies of most, if not all, bats. Does this mean we shouldn't even try to monitor bats?

Response: It may be necessary to shrink our current goals, and be careful to limit studies to those where we can be sure of collecting meaningful data. Clearly some species and problems may be beyond our reach at this time. However, there are new technologies that we should explore. It might be useful to start with the easier problems and species and build to the more complex problems and problematic species as we grow accustomed to new methods. For example, PIT tags and readers may offer alternative ways to mark bats. These marks allow unique identification of individuals. It may be possible to deploy an array of antennae on a number of portals (e. g., a bat gate) and it might then be possible to identify individual bats as they enter and exit the gate. These technologies are expensive now, but the price is likely to decrease in the future.

Seminar

The Group's activities on Tuesday morning began with a seminar on capture-recapture methodology given by David Anderson, Ken Burnham, and Gary White. Highlights of that seminar are presented here. Currently available capture-recapture models are far more powerful than the simple Lincoln-Petersen index more familiar to bat researchers. The purpose of this presentation was to point out some of the strengths and flexibility of modern capture-recapture methods. These provide true population parameter estimation techniques.

The term capture-recapture can be misleading. Programs NOREMARK and MARK (written and maintained by Gary White and available at http://www.cnr.colostate.edu/~gwhite/ without cost) include a variety of models for examining these types of studies. Mark-resight approaches (where marked animals are resighted or re-detected rather than recaptured) are equivalent from a statistical point of view, as long as certain assumptions can be met:

1) Marked and unmarked animals have the same resighting probability;
2) Researchers must be able to correctly distinguish marked from unmarked animals;
3) Depending on the statistical estimator, the researcher must be able to correctly identify individual marked animals.

The power of these methods is that they not only allow the researcher to enumerate populations with known precision, but they also enable the estimation of other population parameters. Depending on the particular model selected, these parameters include: differential mortality among individuals, differential mortality between sex and age classes, and differential detection probability among individual animals. All these are important attributes that we can and should attempt to estimate for bats.

If we can incorporate radio-tagged animals into the design, we can estimate how many animals are available for resighting. The addition of radio-tagged animals then provides a solution to the immigration-emigration problem. A typical field scenario would include the following steps: 1) Mark animals; 2) Resight population and distinguish marked from unmarked individuals; 3) Conduct multiple resightings.

An important point regarding marking and resighting is that the method used to capture animals and mark them should be different than the method used to resight them. With trap-shy animals, captured individuals will avoid being resighted if the same method is used. For example, if mist-nets are used to capture bats and attach marks, mist nets are not appropriate for resighting animals because previously caught animals will avoid nets and violate the assumptions of the model. Similarly, if bats are marked at a roost, the roost may not be the appropriate location for resightings.

Multi-strata models provide extensions of the above and allow the estimation of parameters at several locations as well as the interactions between the locations (for examples, see Hestbeck et al. 1991; Brownie et al. 1993). Multi-strata models also allow the incorporation of environmental covariates (e.g., temperature). If we consider strata to be separate roost locations in proximity to each other, then these models may be especially useful for bat populations where roost-switching occurs and roost environments differ. These models allow independent estimates of survival and other parameters. We can also use multi-strata models to estimate probabilities of detection within each of the strata as well as the probabilities of detection for individuals in transition among strata. It seems reasonable to think that different bat colony locations might have different survival rates and detection probabilities. Multi-strata models may allow us to estimate important population parameters in these types of complex systems.

Following the presentation, there were a number of questions and statements from those attending regarding capture-recapture techniques and programs NOREMARK and MARK. Some of the more relevant questions and responses are paraphrased here; they are not direct quotes.

Question (Kunz): Can we use these methods to separate dispersal from mortality? In bats, we often do not know whether a marked bat has emigrated or died.

Response (White): A robust design model (a specific model of program MARK) can separate these two events. In order to do so however, the model requires population closure. To achieve this, short mark-resight times are necessary.

Question (Kunz): We have seen several models that were derived for use in other taxa (such as deer and elk). Do the unique life histories of bats suggest that other models could be specifically developed for them ?

Response (White): Yes. New capture-recapture models are under development now. There is a list-server for program MARK and we give workshops every summer in June. We also teach a graduate-level course at Colorado State University for those who really want to understand capture-recapture models. Clearly not all of the data that are typically collected for bats will be useful for these models. However, some overlap between the data collected for bats and the data useful for parameter estimation does exist.

Question (Hayes): How can these techniques be applied to larger scales than single locations?

Response (White): This is mostly a sampling issue. First select the sampling frame you are interested in (the particular part of the landscape) and then select random samples (of roost sites) from within that frame.

Question (Kunz and Hayes): How precise do these estimates have to be? I expect we would obtain some pretty imprecise estimates from bats. What precision would be needed for long-term monitoring tools?

Response (Burnham): If the goal was to be able to detect a 5% change in a population over a 10-year period, the estimates would not have to be as precise as you might think, A SE of 20% of the mean measured over a 10-year period would probably be able to show that degree of population change.

Question (Tuttle): We don't know the long-term effects of PIT tags on bats. We need to test these effects before we embark on any massive pit-tagging projects.

Response (Kunz): I have used PIT tags in 7.1 g *Myotis lucifugus* without noticing any ill effects. The tags only weigh about 0.1 g and I have even injected them into pups with no problems so far (three years). There is a small amount of migration of the tags from the injection site, but not much.

Definitions and Monitoring Requirements

The group agreed to use standard definitions for "colony" and "population" during subsequent discussions to avoid ambiguity and to clearly define sampling units. These definitions are:

<u>Colony</u>: A stable group of single species which occupy a definable boundary at a particular time interval where population parameters can be defined.

<u>Population</u>: A group of individuals of the same species living in a particular area at a particular time.

Additionally, we agreed that objectives for any monitoring activity should include: 1) The estimation of population parameters through time that are adequate to detect trends significant to the long-term persistence of the species, subspecies, or population unit; and 2) monitoring should be able to determine changes in species distributions or population numbers.

In any bat monitoring plan, effort should be made first to census the population (completely enumerate the population), and if that is not possible, estimate the population numbers using a robust, defensible technique. If neither a census nor an estimate is possible, an index to population size may have to be developed.

Recognizing that bats are a diverse group of organisms and that there are no overall solutions to the unique problems some groups present for population monitoring, the group divided into four smaller sub-groups. These sub-groups comprised members with particular expertise or interest in the bat categories they considered. All groups were assisted in their deliberations by Dave Anderson, Gary White, John Sauer, or Ken Burnham. The four categories were: colonial species, solitary or "over-dispersed" species, Pacific Island fruit bats, and southwestern pollinators.

Subgroup Report: Colonial Bat Species

Subgroup Members: Bob Berry, Jeff Gore, Michael Herder, Tom Kunz, Mike Rabe, and Paul Racey

Because some bats aggregate in colonies, various methods have been used to estimate the number of bats in a particular colony and to develop estimates of the total population size. However, because bats are highly mobile, inhabit a variety of sites, and display a range of social structures, it is important that a colony be defined and that monitoring times be standardized to ensure that estimates are comparable. As defined, the term colony (a stable, single-species group of bats that occupies a definable area over a particular time interval and for which population parameters can be defined) is most readily applicable to large groups of bats at stable roost sites. However, colonies may also include small aggregations of bats which might use crevices, snags, trees, buildings, mines, or caves as roost habitat. We further suggest colonies be classified into three size classes: small = <200 individuals; medium = 200 - 9,999; or large = >10,000 individuals. This classification system, although somewhat arbitrary, was incorporated because colonies of different sizes pose unique challenges in developing suitable monitoring protocols.

Colonial Bat Species Subgroup Issue 1. Timing of Monitoring Surveys

Issue Description and Rationale. There is considerable variability in the opinions among researchers as to the best time for conducting colony monitoring. Ideally, colonies should be monitored when they are most stable in terms of numbers. While this is sometimes dictated by the physical attributes of the roost, moon phase, or sampling strategy, too often monitoring is scheduled mostly for convenience of the researcher or to maximize the number of counts within a particular season. Monitoring during particular life history events, such as parturition, lactation, or hibernation can cause disturbance or even mortality among the bat species being studied if not approached cautiously. Transient or roost-switching (Lewis 1995) bats complicate the estimation process by introducing an unknown rate of immigration or emigration. Fluctuation in the number of individuals causes great problems in gaining an accurate estimate of colony size. Monitoring during lactation may lead to erroneous assumptions, such as all bats exited the roost, or all bats counted at emergence were lactating females with non-volant young. As young become volant, adults may move to new roosts and form breeding aggregations. Counts made in hibernacula pose considerable disturbance to the bats being monitored and may reduce individual fitness or lead to mortality of the animals. Mortality caused by the monitoring technique compromises the reliability of the count and introduces dilemmas for the researchers. Additionally, as with other aspects of bat population monitoring, lack of consistency in timing between researchers in neighboring areas minimizes the reliability of intercolony comparisons.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Monitoring for a particular species should be standardized with regard to the timing, location, methodology, and data collected. In order to minimize the effect on the counts of transient or roost-switching bats, monitoring should be conducted at a time when the colony size is most stable and most or all of the bats within the colony are exiting the roost. Monitoring at the roost eliminates the problems associated with attempting to assess population trends based upon counts of commuting or foraging bats. Maternity roosts are typically stable and should be the highest priority for monitoring. We recommend that maternity colonies be surveyed in the first week before parturition in order to estimate colony size at its most stable point and greatest size. During this period, most of the bats within the colony should be exiting to forage and transient animals should have moved to other roosts. Counting at this time may require carefully conducted, pre-survey captures to determine the reproductive state of the females of the species, particularly in years where aberrant environmental conditions may alter the timing of reproductive events. Timing of these events may vary due to latitude, climate, or other factors and we encourage the building of predictive models (e.g., those from the U.K., A. Walsh pers. comm.) that would help refine our understanding of the best time to survey.

Monitoring at hibernacula is generally not recommended due to the potential for disturbance to the animals. However, for some species, monitoring within hibernation sites may be the best or only reasonable alternative in obtaining an accurate count with minimal bias. Where this is the case, we recommend monitoring each site once every three years[1]. Hibernation counts are sometimes conducted more frequently in the U.K., but opinions vary on the degree of disturbance involved. A rotational system also may allow more sites to be surveyed. Care should be taken to complete the count as quickly and with as little disturbance as possible.

Colonial Bat Species Subgroup Issue 2. Estimation of colony size and population trends

Issue Description and Rationale. Determining trends in populations requires accurate assessments of colony sizes; where the population comprises colonies dispersed over a wide area, a randomized sampling of colonies should be performed. Unfortunately, different species present different challenges for making accurate assessments. Even within a single species, colonies of

[1]Editors note: Recommendations to conduct counts in hibernacula less often than every year are precautionary, and intended to reduce possible disturbance effects from surveys on survival or reproduction of bats. Other sources recommend conducting counts in hibernacula every two years (Sheffield et al. 1992; U.S. Fish and Wildlife Service 1999).

different sizes or those in different locations may require different techniques or levels of effort. Often biologists select a survey method based more on what appears to be practical rather than on what would provide the most useful and accurate results. This can lead to estimates of colony size that are unreliable or that have no estimate of error. Furthermore, these colony size estimates can prove useless or even harmful when used to detect population trends.

Means to Resolve the Critical Uncertainties Surrounding the Issue.

Census. The preferred method for estimating colony size is a complete count or census and the best census method is to count bats as they exit the roost at night. Observers should arrive at least one hour before the normal exit time for the resident species. Noise and movement by observers should be minimized. Observers should be positioned where they can see the bats but are not likely to be detected by the bats, particularly not directly in the outflight path. At small to medium-sized colonies, bats should be counted until no individuals are seen for 15 minutes at any exit. Larger colonies may have a few bats exiting over a long period, yet staying at the roost may not be efficient. In these cases, it may be helpful to develop and test a depletion count technique that would allow observers to stop counts when less than a designated proportion of the colony is observed exiting over a 15-minute period (e.g., Tuttle and Taylor 1994; Altenbach 1995; Navo 1995).

We recommend two or three separate counts if variation among nights is expected. Double-blind counts conducted by two independent observers would improve the reliability of the count and aid in assessing variation between observers. Following completion of the exit count, observers should refrain from entering the roost to count the number of bats remaining to minimize disturbance to remaining animals. We recommend that a standard form be developed and used by all monitoring crews. Forms should include information such as colony location (including coordinates determined by global positioning systems where useful), number and species of bats counted, number of entrances, moon phase, wind, date, humidity, number and names of observers, sunset, moonrise, noise level, identification technique, counting technique, how multiple exits were accounted for, and a drawing of roost exits if possible. Photographs should be taken outside the colony site if possible.

A variety of equipment can be used to census colonies (Rainey 1995). Infrared thermal imaging, night-vision equipment, and infrared cameras (reflectance-based imagery) may be the only means of counting large colonies. A computer program that counts bats from the infrared imaging is being developed and the testing of this program should be encouraged. For smaller colonies, the above equipment may be useful along with infrared counters, acoustic sensors (as a count starter, camera starter), clickers (tally counters), cameras and lights with red filters.

Estimation. If direct counts of emerging bats are not practical, it may be possible to estimate colony size with capture-recapture techniques. Statistical models are available for determining population parameters and these should be carefully evaluated to determine which are most appropriate for each situation. The capture-recapture models make several assumptions that are often not easily met when working with colonial bats. Most models assume that marked and unmarked animals have the same resighting probability, and this may be violated with any capture technique because bats quickly learn to avoid capture. Because of their small size and reliance on flight, bats are also sensitive to many marking techniques and care must be taken that the marking technique does not cause increased mortality (including predation), significant behavioral changes, or abandonment of habitually used areas. All models also assume that marked animals can be correctly distinguished from unmarked animals. The small size, high mobility, and cryptic nature of bats means that marked animals are often difficult to detect. Conversely, wing bands can be so distinct that marked animals are more likely to be detected. Another problem is that bats can remove or deface bands and other external marks. Finally, depending on the estimation model used, it may be necessary to correctly identify the individual marked animals and this can be a serious problem with bats. New techniques such as PIT tags and microtaggants should be explored for marking bats.

All marking techniques present special concerns and these should be considered along with the advice of a biologist experienced with the species before a marking program is begun. In all cases the need for and expected benefits of a marking program should be carefully considered relative to the potential harm to the bats (see also Working Group C report, issue 5, "Optimizing Information Obtained from Marked Bats"). Some concerns and problems are as follows:

Wing bands: can cause serious injury to some species, some species will not tolerate bands

Necklaces: crevice or foliage roosting bats may snag necklace on projections

Radios: short-lived, expensive, and due to weight and antenna they may cause behavioral changes

Dyes, wing punches, freeze branding: potential for toxicity, short-lived, unknown long-term effect to bat health, research needed

PIT tags: need to focus bat flight through a relatively small space; unknown long-term effects to the bat, research needed

Microtaggants: short-lived, unknown toxicity, research needed

Indices. Indices of colony size are inferior to census or estimation techniques. Therefore, they should be used only as a last resort and their limitations should be recognized. When possible, indices should be calibrated to population size as measured by a census. Indices are most likely to be useful in detecting dramatic changes in population size over long periods of time.

Widely Dispersed Colonies. It is important to note that censusing known colonies may give biased results, depending upon the extent to which there are unknown or undiscovered colonies. Monitoring of known colonies will allow colony extinctions to be recorded, but the formation of new colonies may go unrecorded if attempts are not made to find other significant roosts. Investigators will have to determine the extent to which this phenomenon may occur in their species and adjust sampling designs accordingly.

Colonial Bat Species Subgroup Issue 3. Roost-Switching Between Colonies

Issue Description and Rationale. Colonial bat species are known to switch from one roost to another. Roost-switching may be for the purpose of predator avoidance, a response to predator encounters or disturbance by the researcher, or changes in internal roost conditions (e.g., temperature or parasite infestations). There has been a growth of information on roost-switching in bats since the review by Lewis (1995), but further research is needed to improve understanding of this phenomenon and to properly account for it in population monitoring. Some species or individuals within a colony apparently engage in regular roost-switching, although genetic and other studies in the U.K. and elsewhere indicate that females in maternity colonies are highly philopatric (A. Walsh pers. comm.; Tuttle 1976; Palmierim and Rodrigues 1995). Non-reproductive individuals within the colony may move to separate roosting sites, remain with the colony, or move between the two sites. As females complete lactation and prepare for breeding, they may move from maternity roosts to breeding sites. Migrating bats may join an existing stable colony for a brief period. Fluctuations in the number of individuals introduces substantial variation into counts as this violates the assumption that the colony is a closed population.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Transient and roost-switching animals are not considered in the definition of colony as it is applied here. While several of the Program MARK capture-recapture models can be used to estimate colony size in an open system, it is preferable to use a census technique rather than an estimate. The preferred method for minimizing the effect of roost switching on colony counts is to conduct the monitoring survey when the colony is most stable. In many species this may occur during hibernation or approximately one week before or during parturition. (See also Issue 1 above.)

Colonial Bat Species Subgroup Issue 4. Developing a National Monitoring Program
(See also Working Group C report)

Issue Description and Rationale. Some researchers have proposed the development of a nationwide or continent-wide monitoring program to detect large scale population trends in bats over time. A national program has been employed with relative success in the U.K. However, many North American bat species are widely distributed across the entire country. The scale of nationwide programs in the U.S. could be too large to be feasible if the purpose was to monitor all bat species throughout their ranges (see also Working Group B and C reports). Also, the life history characteristics of some species are either unknown or do not allow for any population census or population estimation to be made in any meaningful way. Nevertheless, some bats in the U.S. have relatively restricted distributions and have life history characteristics that make them likely candidates for a large scale, multi-year monitoring effort. Poorly designed or flawed monitoring programs should not be conducted. It is preferable to miss years or observations rather than conduct widespread, unreliable monitoring of bat roosts. Surveys may pose a possible disturbance to bat colonies. If the information from a survey is likely to be imprecise, then it would be better to not conduct surveys of that colony or perhaps to limit data to presence-absence information.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Target bat species could be selected that have relatively small distributions in the U.S. and whose roosting habits and life histories suggest that such a monitoring plan would be possible (see also Working Group B report, "Prioritizing Monitoring Needs"). After selecting model species, the monitoring strategy could be designed using the following guidelines:

Stratification. All known roosts should be stratified by geographic region, land type, estimated colony size, and proximity to urban areas (see also Working Group C report, Issue 2, "Analytical Considerations for a National Bat Monitoring Program"). This stratification not only reduces the variation among roosts and allows for more precise estimates, but also would allow researchers to examine changes in population sizes among the strata. Roosts would then be selected from these known roosts in a random fashion. Randomizing the sample could pose serious logistical problems but would strengthen the statistical inferences that could be made from any population changes. If random samples pose insurmountable problems, then a non-random selection could be chosen and still be useful. However, the inference from a non-random sample would be restricted to the sample that was being surveyed.

Sample size. A sample size of 25-30 roosts would likely be sufficient to document substantial changes in many populations over time but this may depend on size of the sampling frame. Estimation of sample size requirements and power analysis should be integral to planning efforts (Gibbs 1995; Eagle et al. 1999)

Timing of surveys. All roosts could be sampled once every two or three years rather than every year. Although there is a logistical advantage to yearly surveys (experienced crews remain intact), surveys could be staggered without serious loss of inferential power.

Subgroup Report: Over-Dispersed Bats -- Foliage, Cavity, and Crevice Roosting Bats

Subgroup Members: Tim Carter, John Hayes, Alex Menzel, and Allyson Walsh

Over-dispersed bats roost solitarily or in low densities, generally in foliage, cavities, or crevices. Characteristics of over-dispersed bats present unique problems with respect to monitoring and estimating population parameters. The roosting ecology of these species limits applicability of methods described for colonial species. Furthermore, the high vagility, low detectability, and low probability of recapture make it difficult to apply mark and recapture or resight methods for estimation of population parameters.

Over-Dispersed Bats Subgroup Issue 1. Estimation of population parameters of over-dispersed bats

Issue Description and Rationale. Estimating the density or survival of over-dispersed bats is necessary to monitor trends of these species. Trends in densities could be used to monitor the effects of factors such as habitat manipulations and changes in climatic patterns on the health or spatial distribution of populations of over-dispersed bats. Currently, two methods (use of bat detectors and mist nets) are used to determine indices of abundance for these species in limited geographic areas. We currently have no understanding of detection probabilities (i.e., the probability of detecting an individual with a given technique under specified conditions) associated with each of these methods, and it may be impossible to standardize detection probabilities among researchers or studies and over time. Thus, it is not possible to determine the precision or accuracy of these indices. Without an understanding of accuracy and precision, it is difficult to determine if trends based on these indices reflect actual changes in population densities or changes in the detection probabilities. The inability to estimate detection probability greatly limits the usefulness of data collected using uncalibrated indices produced either by mist netting or bat detector surveys. To calibrate these indices, appropriate population parameters must be estimated. Currently, these population parameters can only be estimated using mark-resight techniques. To date, mark-resight techniques have not been developed or applied to estimate population parameters for any species of bat in this group.

Means to Resolve the Critical Uncertainties Surrounding the Issue. The uncertainty and problems associated with this issue are substantial and daunting. The problems revolve around uniquely marking and resighting animals. No methodologies have yet been developed or applied for marking and resighting or recapture of over-dispersed bats in an economical or logistically feasible manner. Problems associated with recapturing members of this group make utilization of unique marking techniques like forearm-banding inappropriate. Other techniques used to individually mark animals include radio-transmitters and PIT tags. Because of the high cost associated with radio-transmitters, their use for marking animals to estimate population parameters may not be economically feasible. The short distance required between the PIT tag scanner and the bat to detect the PIT tag limits their use for over-dispersed bats. Technological advances may alleviate many of these problems. Technological advances including transponders and diode lights may make marking and resighting large numbers of over-dispersed bats economically and logistically feasible.

Until problems surrounding estimation of population parameters are resolved, alteration of current methods to increase statistical rigor is desirable. Current limitations of indices may be reduced through the use of double sampling procedures (Thompson et al. 1998, p. 115), in which an inexpensive index is gathered in a large sample followed by expensive but more reliable measures on a smaller sample, results of which are used to calibrate the index. For bats, perhaps mark-resight or other enumeration techniques can be used to calibrate more expensively measured parameters (e.g., density) to more easily measured indices (e.g., habitat type, mist-net captures, bat detector data).

We suggest two initiatives regarding existing monitoring and research programs. First and most importantly, it is essential that methodologies be developed to determine unbiased estimates of population parameters such as abundance, density, and survival of over-dispersed bats. Without such methodologies, it will never be possible to reliably monitor trends in populations of these species. These methodologies will likely involve new approaches for marking and resighting bats.

Second, once methodologies for mark-resight studies are established, evaluation and calibration of widely used methodologies and indices, such as catch per unit effort from mist-netting or number of bat passes in echolocation monitoring studies, is necessary. Current methods employed for surveying or monitoring over-dispersed bats are primarily limited to mist net and bat detector surveys. Because detection probabilities associated with these methods are unknown, data currently collected using these techniques are of limited value. The precision of data currently collected should be evaluated. Provided data collected by these indices are positively and significantly correlated with the population parameters they are intended to estimate, their usefulness will be greatly increased through calibration.

Because of the expense and logistical difficulties currently associated with estimating the population parameters of over-dispersed bats, it is unlikely that indices currently used can be calibrated adequately by a single study or research team. Because data used in calibration will probably be collected in multiple studies by many individuals, the manner in which the mist netting and bat detector data are collected should be standardized to the degree possible. Following calibration of these indices, the usefulness of index data collected in the future will depend on the collection methods paralleling those used in the calibration studies.

Over-Dispersed Bats Subgroup Issue 2. Use of echolocation-monitoring to determine trends in habitat use by over-dispersed bats

Issue Description and Rationale. Bat detectors have become increasingly available over the past decade, and are used for long-term monitoring of bats. For example, nationwide monitoring programs in the U.K. (Walsh and Catto 1999) and the Netherlands have incorporated use of bat detectors as one tool for monitoring bats. In the U.K., surveys using heterodyne bat detectors are conducted during the summer to complement counts at maternity colonies or hibernacula for five species of bats. Because of the difficulties in capturing over-dispersed bats in many environments, use of bat detectors to evaluate trends in bat populations would be a cost-efficient, non-invasive technology if crude indices based on echolocation detectors could be calibrated against actual numbers of bats.

A central problem in use of bat detectors is the inability to use echolocation-monitoring data to assess number of individuals using a site and hence measure absolute abundance. For example, it is not possible to distinguish between a single individual flying over a given site on ten occasions, and ten individuals each flying over the site once. Hayes (submitted ms) identified and discussed assumptions inherent to use of bat detectors in echolocation-monitoring studies. Hayes concluded that it is unlikely that echolocation-monitoring data can be an effective tool for assessing population trends of bats because such data do not assess abundance directly. However, Hayes noted that under some situations bat detectors may be appropriate for monitoring use of different habitats through time if care is taken to assure adequate spatial and temporal replication. Bat detectors also may play a valuable role in monitoring changes in species distributions for taxa that can be identified unambiguously based on echolocation calls.

Means to Resolve the Critical Uncertainties Surrounding the Issue. It is recommended that use of bat detectors in monitoring programs for over-dispersed bats be used only with recognition of the limitations restricting inference to changes in species distributions and use of habitats rather than changes in abundance. Studies using infrared video recorders and at least two observers may be valuable in quantifying the relationship between numbers of bats and bat passes in different habitats.

Over-Dispersed Bats Subgroup Issue 3. Use of mist-netting surveys to evaluate trends of over-dispersed bats

Issue Description and Rationale. A large number of inventories and studies of bats using mist nets are conducted each year across the United States. Some of these efforts, including surveys conducted on public and private lands, are specifically targeted at determining status of species. However, these surveys generally only provide meaningful information on the presence and distribution of species, and rarely if ever provide reliable information on abundance or density of populations. Many other mist-netting efforts are targeted to achieve a variety of objectives such as capture of individuals for radio-telemetry or collection of fecal pellets for dietary analysis, and information on number of individuals captured and presence of species is incidental to the primary objective. A central problem with these data is a lack of consistency in approaches used to collect the data. Furthermore, there have been minimal efforts to date to evaluate large-scale patterns in numbers of captures of bats using these data.

Because of the inability to assess population parameters using mist-netting data in the absence of recapture or resighting information (see Issue 1, this subgroup report), meaningful estimates of changes in population density based on data currently collected in mist-netting surveys and studies are not possible. Changes in numbers of captures over time can result from changes in capture probabilities or from changes in abundance.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Uncertainties concerning interpretation of mist-netting data and the extent to which changes in numbers of captures reflect changes in abundance or changes in capture probabilities preclude use of these data for unbiased estimation of population trends. However, in the absence of improvements to current approaches, we suggest that methods for collecting and compiling data collected in mist-netting studies and surveys might provide a valuable “early warning system” to monitor major trends in populations of over-dispersed bats. An early warning system using mist-netting data would enable identification of probable changes in the distribution of species through time, and would provide evidence of potential dramatic changes in abundance of species. The rationale for the application of mist-netting data as an early warning system relies on the principle that capture probabilities are not likely to change beyond certain bounds through time (assuming no significant changes in capture techniques). If capture success for a species changed through time, and if the magnitude of change exceeded the maximum rate expected given changes in capture probability, this would suggest a significant change in abundance. For example, if one assumed that a change in capture probability by a factor of 10 was highly unlikely, than any ten-fold change in number of bats captured would be unlikely to result from changes in capture probabilities alone, and would likely be the result of changes in abundance. In addition, mist-netting data could be used directly to assess distribution of species and changes over time. If apparent changes in distribution or abundance of species were noted that were substantial enough to be of potential conservation concern, additional, more rigorous studies could be pursued.

Implementation of this approach would require two changes. First, standardization of mist-netting methodologies is essential to provide data that are reasonably comparable among studies. Capture probabilities are a function of a variety of factors, some of which are under the control of surveyors, others are not. Controlling for as many of the factors known to influence capture probability as possible may increase the probability that changes in capture success reflect changes in abundance. Standardization of factors such as time nets are deployed, duration of deployment, and weather conditions during which netting is conducted will help control for some of this variation. (However, standardizing counting protocols alone does not satisfy constant proportionality assumptions inherent in use of indices [Thompson et al. 1998, p. 77]). In addition, recording data concerning the size of nets used, location of sites, habitat characteristics of the area, and ambient conditions (e.g., temperature) may provide useful covariates for future analyses. However, because all factors related to capture probabilities cannot be controlled or taken into account in future analyses (indeed some of the factors responsible for differences in capture success will probably not even be known), use of these data will only be valuable to address coarse-scale changes of relatively large magnitude. Second, data collected from mist-netting studies would need to be archived in an accessible format so that trends could be evaluated.

While we advocate the use of this approach as an early warning system, we offer three caveats. First, the lack of statistical rigor inherent to this approach should be recognized, and managers should not misinterpret *potential* trends identified with this approach as *actual* trends. Second, only substantial trends will be apparent using this approach; important, but smaller trends will not be identifiable using this approach. Finally, use of this approach should not divert resources from development of more rigorous procedures for evaluation of actual trends.

Over-Dispersed Bats Subgroup Issue 4. Spatial scale considerations in monitoring over-dispersed bats

Issue Description and Rationale. Determining the appropriate spatial scale for monitoring is a critical issue (see also Working Group C Report, Issue 2, “Analytical Considerations for a National Bat Monitoring Program”). Monitoring programs can be established to evaluate population trends at a variety of spatial scales, from very small, localized populations (e.g., at a scale of several hectares) to regional trends (e.g., within states or regions of the country) or at very expansive spatial scales (e.g., nationally or across the entire distribution of the species). Real or apparent trends at very restrictive spatial scales could be an artifact of localized conditions or stochastic variation that is offset by counter-trends within other small populations. As a consequence, monitoring at very fine spatial resolutions is likely to be of value to managers only under limited situations. For over-dispersed bats, the appropriate scale to provide meaningful information for conservation or management of bats will generally be at the regional or higher spatial scales.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Pending development of techniques to better estimate population parameters for this group of bats (see Issue 1), progress may be limited. However, methods to determine sampling protocols at different spatial scales are well-developed in the statistical and sampling literature (e.g., Goodwin and Fahrig 1998). If feasible, sampling protocols based on stratified random sampling of large areas probably would be most appropriate for this group.

The resources required to implement even modest efforts for a well developed, statistically rigorous, large-scale monitoring program for over-dispersed bats would be considerable. It is unlikely that technological advances in approaches to monitor bats will alter this in the foreseeable future. Compilation of data from existing mist-netting, trapping, or bat detector studies may be an alternative to development of rigorous large-scale sampling for these species. However, the previously mentioned caveats concerning these methods should not be overlooked.

Over-Dispersed Bats Subgroup Issue 5. Alternatives to monitoring

Issue Description and Rationale. Because of difficulties noted above in monitoring populations of over-dispersed bats, current evaluation of population trends in bats may require use of alternatives to monitoring. One valuable alternative approach is based on the premise that causal factors related to abundance, survival, or recruitment of bats could be identified, and the extent to which those causal factors are expressed in some geographic area would reflect status and changes in population parameters through time. Studies of the response of bats to habitat structure or environmental perturbation conducted at appropriate spatial scales could serve as surrogates for monitoring. Applicability of data collected from these studies beyond the area studied should be tested to determine the limits of their applicability (e.g., spatial and temporal scale).

Means to Resolve the Critical Uncertainties Surrounding the Issue. Double sampling is a method that can be used to statistically calibrate surrogates (e.g., Thompson et al. 1998). This method uses mark-resight or other reliable enumeration techniques to calibrate expensively measured parameters (e.g., density) to more easily measured parameters (e.g., habitat type). Following development of appropriate methodologies, studies should involve the use of mark-resight techniques to obtain population densities in limited areas. Causal factors that may influence density should be identified and evaluated. Then extrapolation can be done across a limited area where similar factors occur. Although initial studies correlating potential causal variables and population parameters will be costly and time consuming, measurement of the surrogate variable across the inference area should be relatively easy.

There are many examples of studies of relative use of different areas by bats. Because most of the methods do not account for detection probability, many of these approaches lack statistical rigor. We recommend that future studies attempt to evaluate population density, rather than an index of abundance, wherever possible. Furthermore, these programs should include double sampling methods to extrapolate results to wider spatial scales.

Subgroup Report: Assessment of Population Size and Trends in Pacific Island Fruit Bats

Subgroup Members: Anne Brooke, Ruth Utzurrum, Gary Wiles, and Don Wilson

In the geographic areas under consideration, American Samoa, Guam, and the Commonwealth of the Northern Marianas, there are three species of fruit bats: *Pteropus mariannus*, *P. samoensis,* and *P. tonganus.* A review of census methodology and population trends for these three species appears in Wiles et al. (1999). In general, these three species fit into two basic lifestyles: colonial and solitary.

Pteropus samoensis is solitary, with individual bats roosting alone in the canopy of the forest. Most animals spend at least part of their time foraging actively during the day, and their tendency to soar and ride thermals makes them visible to properly situated observers. For the past decade or so, relatively standardized counts of flying bats over given periods of time have been made at permanently located stations. The numbers generated by these counts are used as an index to the health of the population on the largest island in American Samoa.

Pteropus tonganus occurs in colonies ranging from dozens to thousands of bats. The colonies are relatively easy to detect, although hunting pressure in years past in American Samoa has driven the colonies to the most inaccessible parts of the islands. Once colonies are located, it is possible to census them by direct counts using binoculars and spotting scopes, but there is considerable variation in the counts, due to differential detectability of animals within a colony. It is also possible in some cases to make dispersal counts on colonies. These counts are also subject to some unknown amount of variation due to potential differential dispersal routes for the colonies. Some unknown (although probably small) percentage of the population also roosts solitarily and is well dispersed with regard to known colonies.

Pteropus mariannus has a lifestyle similar to that of *P. tonganus*. Most animals live in colonies that are relatively easy to detect. However, an unknown percentage (possibly somewhat higher than in *P. tonganus*) also lives solitarily at any given time. On Guam, a single remaining colony has been censused monthly by direct counts by the same individual for the past 15 years. These counts are reasonably reliable, and the population estimates for Guam are probably the most sound of all three species and of all other areas. Counts on other islands in the Northern Marianas are less reliable, and have been conducted regularly only on a single island (Rota). Counts on these islands are done with combinations of direct colony counts, indirect departure counts, and counts of flying bats at widely dispersed observation stations. Some unknown colonies likely remain to be detected.

Pacific Island Fruit Bat Subgroup Issue 1. Difficulties in Censusing Pacific Island Fruit Bats

Issue Description and Rationale. P. samoensis presents the most intractable problems among the three species. Its solitary roosting habits and dispersion through inaccessible forest in extremely rugged terrain makes censusing difficult. The station counts have been performed by different observers over time and the techniques themselves have been modified slightly at different times. This makes even relative comparisons somewhat difficult to make. There is a need for a means to measure detectability, and for a means to extrapolate the findings from the areas surveyed to the entire population.

P. tonganus presents a different, but related set of problems. Probably not all roosts are currently known. Improved means to detect all roosts on a given island are needed. Counting individuals within a known roost is also difficult. There is a need for better methods of standardizing these counts, and of getting some measure of inter-observer differences. These problems apply equally to dispersal counts conducted at *P. tonganus* roosts.

The problems with *P. mariannus* are similar to those outlined for *P. tonganus*. Especially in the Northern Marianas, we need to locate all of the colonies on a given island. Once located, the colonies need to be censused in a more standardized fashion, allowing some indication of individual observer differences. In addition, some improved technique for estimating the size of the population that occurs as solitary individuals is needed.

Means to resolve the critical uncertainties surrounding the issue. We met with David Anderson and discussed a variety of methodological approaches to censusing these species. Use of mark-recapture methods appears stymied at present by our current inability to reliably capture the animals for marking. In turn, distance techniques that rely on some measure of detectability seem precluded by logistical difficulties.

For all three species, the most pressing need is for a measure of detectability that would allow more accurate estimation of the total population from current counting techniques. We believe that research directed towards improving the census methodology in that direction should be pursued. Probably the most promising area is to devise a method of capturing the animals that would allow marking. If we had a marked proportion of animals in any of our study areas, it would allow us to begin the process of injecting more rigor into the statistical analysis of our count data.

Additionally, research into attracting animals using artificial lures might be profitable. Recordings of calls, or artificially generated call simulations, might allow bats to be attracted to sites where they could be counted or marked. Similarly, research directed at using scent stations based on actual food sources, or chemically enhanced stimuli, might be useful. If the bats could be attracted to some sort of bait station, it would greatly increase the chances of capturing and marking them. If bats can be attracted to chosen sites, we would also need additional research into methods of netting or trapping them. Methods of self-marking at such bait stations should also be explored.

We also recommend additional study into the possibility of controlled hunts in some areas or some islands. This might be especially useful if some method of marking animals is developed. Such hunts might increase involvement of the local people in conservation activities by allowing their participation in a worthwhile scientific endeavor, while at the same time enjoying traditional hunting activities that are currently denied.

Additional research into the feasibility of using aerial surveys and remote sensing information to detect colonies of both *P. tonganus* and *P. mariannus* would be useful. In the interim, the currently used census methods should be continued and every possible effort should be made to standardize them as much as possible. In addition, logical covariates of bat population densities also should be measured regularly, with a view towards explaining future trends.

Subgroup Report: Improving Assessment of Numbers and Trends in Southwestern Pollinators

Subgroup members: Mike Bogan, Paul Cryan, Virginia Dalton, Ted Fleming, Rodrigo Medellin

Three species of nectarivorous bats seasonally occur in the southwestern U.S. (primarily Arizona and New Mexico); the greater part of their geographic ranges are in Mexico. During the spring and summer they migrate northward into the United States as flowering plants (columnar cacti and agaves), upon which they depend for sustenance, begin to bloom. These three species play an important, but not clearly understood, role in southwestern ecosystems, primarily by providing pollination and seed-dispersal services. The three species are:

Leptonycteris curasoae, Lesser Long-nosed Bat. Most of the major roosts are in Mexico. The species occurs seasonally in several large maternity roosts in southwestern Arizona and in smaller numbers in southeastern Arizona and southwestern New Mexico. The species is listed as Endangered by the U.S. Fish and Wildlife Service (FWS).

Leptonycteris nivalis, Greater Long-nosed Bat. Little is known of this species although it occurs in some large roosts in Mexico. In the U.S. it is known only from southwestern New Mexico in late summer and from one cave roost in Big Bend National Park in Texas. The species is listed as Endangered by the FWS.

Choeronycteris mexicana, Mexican Long-tongued Bat. This species ranges from Honduras northward into southern Arizona and New Mexico in the spring and summer. The species is a former FWS Category 2 Candidate Species and is now considered a “Species of Concern.”

Southwestern Pollinator Subgroup Issue 1. Relative value of current efforts to monitor *Leptonycteris curasoae*

Issue Description and Rationale. Leptonycteris curasoae is listed as Endangered in the U.S. and is of special concern in Mexico. Monitoring programs are currently in place in Mexico and are conducted by the Program for the Conservation of Migratory Bats (PCMM). Roost sites are visited once a month or every other month. During each visit, census data are collected in a standardized fashion (data also are recorded for *L. nivalis*). The program hopes to detect both long-term declines and catastrophic events (e.g., vandalism, etc.). Despite the Endangered status of *L. curasoae*, there is no coordinated monitoring program in the U.S. Efforts to monitor the species in the U.S. have been conducted by several individuals in a non-standardized fashion; monitoring in the U.S. is not coordinated with Mexican efforts. Current techniques involve counting bats in, or as they exit, their roosts.

Current efforts are based on two major assumptions. The first assumption is that there is an equal likelihood that bats will return to the same site year after year. The second assumption is that there is minimal movement of bats between roosts during the monitoring period. Based on our current knowledge of these species, we are confident that these assumptions are not seriously violated in current monitoring efforts and that such efforts are producing useful information on population trends in roosts.

Means to Resolve the Critical Uncertainties Surrounding the Issue. The subgroup agreed that current census efforts provide sufficient resolution to monitor major population trends and catastrophic events and should be continued. Additionally, the PCMM is a valuable conservation and education effort that should continue in Mexico. Nonetheless, current efforts are low resolution and should be improved. Deficiencies of the current system and ways to improve these efforts, including using a standardized monitoring approach throughout the range of the species, are discussed in the context of Issue 2.

Southwestern Pollinator Subgroup Issue 2. Standardizing monitoring techniques for *Leptonycteris curasoae*

Issue Description and Rationale. An important existing problem is the absence of a standardized approach to counts over time and space. The following issues and possible solutions are important in attempting to develop a standardized counting protocol for *L. curasoae* and may also be useful for the other two species of pollinating bats in the U.S.

Means to Resolve Critical Uncertainties Surrounding the Issue.

a. *Methods of counting emerging bats*. Comparisons of counts made from videotapes to real-time visual observances suggest that videotaping the emergence provides the most reliable way to count (Dalton and Dalton 1994). All counts of videotaped emergences should be made by two individuals until counts converge. Video also has archival properties and digital images may be quantified with computer methodology that is in development. The subgroup recommended that a cascade of approaches be used with infrared videotaping preferred where and when equipment is available. In the absence of that equipment, internal or exit counts should be made by at least two or more observers. Using only a single observer is not recommended, as then no error estimate is possible.

b. *Types of illumination used during exit counts*. It is likely that both white light and red-filtered light modify bat behavior. We recommend the following light types, in order of preference: 1) infrared light, 2) red-filtered light, 3) white light.

c. *Length of emergence counts*. Current efforts generally count through a period that is believed to approximate the major portion of the emergence, about two hours, and this seems adequate. It might be useful to obtain more precise data on length of emergences.

d. *Covariates that should be recorded during exit counts*. We recommend that the following covariates be recorded: time of day, length of time for emergence, presence and relative amount of nearby water, wind speed, temperature, other climatological factors, phenology of flowering plants important to bats, and other noteworthy items, including evidence of disturbance. These factors may be used as covariates to help explain variation in colony numbers.

e. *Counting target species in roosts with multiple species*. Multispecies roosts confound exit counts at many of the significant roosts of *L. curasoae* in Mexico. Suggested solutions include doing an internal count first to determine the proportion of each species in the roost, then conducting the emergence count, and adjusting the number by proportion present (this should be tested for reliability and, ideally, two observers should estimate proportions and numbers). Videotaping and still photographs may also provide estimates of proportions of other species in the roost. Additional work is needed to further address this problem.

f. *Minimum number of observers needed to make counts*. This varies by site to some extent but as noted earlier, at least two individuals should count bats, whether on tape or during emergences. Those in charge of monitoring roosts should attempt to get additional help when needed. In the U.S. this may be less of a problem because there are fewer roosts and a shorter season in which roosts must be monitored.

g. *Standardized descriptions of roosting sites (caves, mines)*. We recommend that attempts be initiated to develop more or less standardized descriptions for roosts of this species. Most important are descriptions of roost configuration (e.g., location, shape and size of main exit, number of exits, passages, length, etc.). A standardized protocol to describe these and related aspects of roosts may be useful. In Mexico, PCMM uses a speleologist to go to each cave that is monitored and provide cave maps with entrances and other details. In addition, qualitative descriptions of nearby vegetation, nearest available water, and selected microclimate variables should be included.

h. *Ranking of roost sites in terms of biological or conservation importance*. In Mexico, due to the number of roost sites and the fact that they cannot all be monitored in one year, roosts are ranked for monitoring purposes. Rankings are based on the number of bats present, status of species occupying the cave, species richness, proximity of the roost to threats (e.g., urban areas), and location of the roost in relation to migratory routes.

i. *Standardized schedule for exit counts.* Ken Burnham noted that if we are only trying to monitor long-term changes due to environmental degradation we do not need to monitor every year. If there is a need to check sites for catastrophic changes or vandalism this can still be done without conducting exit counts on every visit. This may allow more roosts to be covered in a given period (e.g., every two years).

j. *Standardizing counts of bats inside caves or mines*. In Mexico, the configuration of some caves limits the feasibility of emergence counts as observers or video equipment cannot be usefully located. Thus, internal counts are the only possible means of counting. We recommend that in such situations the counts be conducted by two observers (see also Altenbach 1995), so that error estimates can be made.

k. *Importance of transient roosts for monitoring*. There are potentially important transient roosts in southeastern Arizona in early and late summer that are likely dependent on a localized food resource. These bats may represent a presently unknown maternity colony in northeastern Sonora. Even though we are uncertain of the importance of some transient roosts there was a consensus that exit counts should be conducted at these sites as well.

l. *Disturbance of bats during monitoring activities*. There was general agreement that bats may move due to disturbance but that such moves are temporary. Nonetheless, counts and other activities should be conducted with the least possible disturbance to the bats.

Southwestern Pollinator Subgroup Issue 3. Monitoring of *Leptonycteris nivalis*

Issue Description and Rationale. In Mexico, PCMM is trying to identify gaps in the information pertaining to *L. nivalis* and will initiate further work in the future. In the U.S., the only known roost of *L. nivalis* is at Mount Emory Cave, Big Bend National Park, Texas, and occasional individuals have been captured in New Mexico.

Means to Resolve the Critical Uncertainties Surrounding the Issue. We recommend that the National Park Service initiate or allow routine monitoring of Mount Emory Cave, as well as searching the area around Mount Emory Cave, and perhaps adjacent areas, for additional caves that may be used by *L. nivalis*. Researchers in New Mexico and southeastern Arizona should be alert to the possibility that they may capture *L. nivalis* at times. Such instances should be recorded and forwarded to a central clearinghouse for information on the species.

Southwestern Pollinator Subgroup Issue 4. Monitoring of *Choeronycteris mexicana*

Issue Description and Rationale. We discussed monitoring needs of *C. mexicana* as a part of our activities. The U.S. Geological Survey conducted a search for all historic roosts of this species in Arizona and New Mexico during summer 1999 (Cryan and Bogan in prep.). Site fidelity was high, occupancy rates were consistent with historic numbers, and females were frequently accompanied by young. This species may be an example of an "over-dispersed " species, and comments elsewhere in this report may pertain as well (see Working Group A subgroup report, "Over-Dispersed Bats").

Means to Resolve the Critical Uncertainties Surrounding the Issue. Given the generally favorable nature of the 1999 survey results (Cryan and Bogan in prep.) along with comments by Ken Burnham on needed frequency of actual counts, we recommend that the survey be repeated every two to three years. *Choeronycteris* appears to be amenable to a recruitment and survivorship marking study because individuals are visible from outside the roost, they are found in manageable groups, and they are relatively limited in distribution (patchy). There was a consensus that this would be worthwhile only as part of an in-depth, long-term research study of the biology of the species. Given the ability to make actual counts, marking of individuals is not needed for monitoring efforts.

Southwestern Pollinator Subgroup Issue 5. Continuation of Baseline Monitoring Efforts

Issue Description and Rationale. The subgroup agreed that efforts to establish baseline monitoring information and data for these three species should be continued. There was a further consensus that this probably has to be done on a species-by-species basis. There is not enough monitoring directed at *L. nivalis*, and the first attempt at a range-wide survey for *C. mexicana* in the U.S. was just completed this summer (Cryan and Bogan in prep.). In addition, efforts should be continued to find new roosts, particularly in areas where there are gaps in the known current range.

Means to Resolve the Critical Uncertainties Surrounding the Issue. As noted earlier, with relatively long-lived species, such as bats, it is not necessary to monitor every year to pick up long-term trends in population. Given current budgets and resources available for monitoring, monitoring every two years could increase the number of roosts monitored over time, particularly in Mexico. However, annual counts are useful for picking up short-term changes, catastrophic events, and gathering data on covariate influence on population numbers.

Southwestern Pollinator Subgroup Issue 6. Sharing of Baseline and Monitoring Data for the Three Species

Issue Description and Rationale. In the case of *L. curasoae* we have two types of data: roost locality/characteristics data, and data on counts of bats at roosts. We agreed that precise locality data must be controlled and released only to qualified individuals. We also reached a consensus that we need a central repository for all data, but at this time could not agree on where that would be. In Mexico, the Comision Nacional Para El Conocimiento y Uso de la Biodiversidad (CONABIO)[2] will fund projects to gather data. The data are the collector's for five years after collection, but then become available to others, unless the collector specifically requests controlled access to data. Then the collector becomes the gatekeeper to data. PCMM posts metadata rather than specific data.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Efforts should be continued to identify a central clearinghouse for information on the three species as well as to resolve differences about exactly what data should be stored and what should be released to various parties interested in the data.

Southwestern Pollinator Subgroup Issue 7. Funding for Monitoring and Research

Issue Description and Rationale. Funding for this group of unique pollinators seems relatively difficult to obtain, other than for specific research studies. Recovery plans have been written for the two endangered species of pollinating bats, but we were uncertain whether the plans are being implemented. Both plans contain fairly complete synopses of useful and important research and management activities that should be conducted as a part of the recovery of the two species.

Means to Resolve the Critical Uncertainties Surrounding the Issue. Efforts should be initiated at Federal and State levels to obtain funding for collecting baseline information on these species and for long-term population monitoring. Current interest in pollinators may provide a useful springboard for efforts to obtain such funding. Discussions on the status of recovery plans and the need to initiate greater levels of activity should be held with Department of Interior agencies that have lands on which these species occur or that have mandated responsibilities under the ESA.

Southwestern Pollinator Subgroup Issue 8. Associated Research Activities

We discussed the potential of more sophisticated monitoring regimes (e.g., mark and recapture studies) for estimating population parameters. Ken Burnham noted that such approaches should best be reserved only for research purposes and should not be used for long-term monitoring given the geographic distribution of roosts and logistical difficulties of moving among roosts. Banding studies would help identify movement between colonies, provide information on site fidelity, and allow some inferences on natality and mortality. However, such studies would require thousands of marked individuals and intensive follow-up monitoring.

Several factors confound our ability to monitor these species. Migration, and our relative ignorance of it, makes decisions on sampling and sampling frames difficult. It might be possible

[2]Editor's note: CONABIO is an interministerial Mexican government commission established by Presidential decree March 16, 1992. The mission of CONABIO is to coordinate conservation and research efforts designed to preserve Mexico's biological resources. For additional information see http://www.conabio.gob.mx.

to use a particular season of the year when the bats are most concentrated within their range and those sites could be sampled, however this information is not currently available. If winter is the time of greatest concentration of *L. curasoae* , then it may be possible to count all 30 known wintering sites (estimated). If all sites cannot be visited within a short period, sampling priorities could be established (e.g., by using numbers of bats present), and then a sample of caves/roosts could be selected.

Indirect methods, such as monitoring bat visitation at flowers and feeders may offer promise in identifying areas of new or unknown roosts and times of arrival and departure. In addition, there may be some use for molecular tools in assessing historical, long-term population numbers but only for research purposes. Finally, there may be a potential role for non-specialists in these efforts, in Mexico to help define migration corridors, and in the U.S. to monitor bat use of hummingbird feeders.

Working Group B. Prioritizing Monitoring Needs

Working Group Members: Pat Brown, Mary Kay Clark, Joe Kath (Leader), Allen Kurta (Rapporteur), Kirk Navo, David Saugey, Merlin Tuttle, Ernest Valdez, Mike Wunder

Monitoring any population of animals generates a wealth of biological information, including increased knowledge of natural history, ecology, and behavior. Such information is potentially useful to wildlife managers and research biologists and can be of interest to the general public. In addition, data obtained by monitoring are essential for demonstrating demographic trends that are important to conservation.

Although it may be intrinsically desirable to monitor all species, such an undertaking may not be necessary or practicable. Before beginning a monitoring program, one must establish the:

- goal of the monitoring program,
- feasibility of the monitoring program, and
- criteria to be used when deciding which species or population to monitor.

In this paper, we focus on the latter two issues and examine various biological and non-biological factors to consider when deciding which group of bats to monitor. Our discussion touches on six broad categories of factors that are not mutually exclusive. These categories are: (1) distribution; (2) feeding strategy; (3) roosting habits; (4) population status; (5) threats; and (6) reality.

1. Distribution

Bats display an array of geographic distributions. Some, such as the hoary bat (*Lasiurus cinereus*), occur across the North American continent, whereas others, such as Wagner's mastiff bat (*Eumops glaucinus*), are found only in small portions of a single state. Other species with limited distributions are restricted to oceanic islands (e.g., Samoan flying fox, *Pteropus samoensis*) or to islands of uncommon habitat (e.g., Mexican long-tongued bat, *Choeronycteris mexicana*, in the Sonoran Desert). In general, taxa with localized distributions are more amenable to monitoring because of logistic considerations, and those species often are more in need of monitoring because of their presumed smaller population sizes. A related concern is the disjunct distribution of some taxa, such as the Virginia big-eared bat (*Corynorhinus townsendii virginianus*). Although the entire range may appear large, the individual, isolated populations may be highly vulnerable and, thus, more in need of monitoring.

The size of a species range is one consideration, but location of that range in relation to human activity may be equally important. Humans are capable of drastically altering the landscape, and bat populations occurring within areas undergoing rapid change are of particular concern. Large-scale changes, such as urban sprawl, rural development, habitat fragmentation, and artificial conversion of forest types may negatively impact bat populations by altering roosting and foraging habitat (Carter et al. 1999). For example, in the southeastern United States, a rapidly expanding human population coupled with fragmentation and loss of bottomland hardwood forests (Carter et al. 1999; Clark 1999) may signal a need for monitoring activities in that region.

2. Feeding Strategy

Bats in the United States and its Trust Territories have three broad feeding strategies: insectivory, nectarivory, and frugivory. Most species are insectivorous, but available data on specific dietary items vary considerably across species and season (e.g., Ross 1961; Whitaker 1972, 1988, 1995; Black 1974). Even for those taxa that have been studied in greatest detail, dietary components generally have been identified only to the level of order and, occasionally, family. To understand better the role of bats in their ecosystems or their economic value to forestry or agriculture will require identification of prey to the level of genus and species. Detailed studies have shown the economic importance of at least two species of North American bats that prey on crop pests. The Mexican free-tailed bat (*Tadarida brasiliensis*) preys on corn earworm moths (*Helicoverpa zea* [McCracken et al. 1997]), and the big brown bat (*Eptesicus fuscus*) consumes large numbers of cucumber beetles (*Diabrotica* sp.), the larvae of which are the destructive corn rootworm (Whitaker 1995). Because most bat communities in the United States are insectivorous and the diet of most species is so poorly understood, prioritizing monitoring needs based on diet does not seem reasonable for most parts of the country.

There are only three nectarivorous species (*Leptonycteris curasoe, Leptonycteris nivalis*, and *Choeronycteris mexicana*) and one frugivorous species (*Artibeus jamaicensis*) that occur in the U.S., although several others are found in various Pacific and Caribbean territories (see also Working Group A, "Pacific Island Fruit Bats" and "Southwestern Pollinators" subgroup reports). Nectarivorous species are functionally important in their ecosystems because of their role in pollinating various plants. For example, the three species found in the United States are important pollinators of columnar cacti and paniculate agaves, even though they spend only a portion of the year in the southwestern part of the country (Fleming et al. 1999). Nectarivorous species often eat fruit and function as seed dispersers, in addition to their role as pollinators. Similarly, frugivores are functionally important, acting as seed dispersers and occasionally as pollinators for a variety of tropical plants. On some Pacific Islands, pteropodid bats are responsible for dispersing the seeds or pollinating the flowers of more than 50% of the species of native woody plants (Fujita and Tuttle 1991; Banack 1998). In areas where the ecological or economic importance of bats has been demonstrated, feeding strategy is one factor that might be considered when prioritizing monitoring needs.

3. Roosting Habits

Roosting habits of bats are highly varied, but in general, roosting sites can be categorized as either “natural” or “anthropogenic” (Pierson 1998). Natural roosts include caves, rock crevices, and trees. Trees, in turn, provide roosting sites underneath loose bark, in cavities or crevices, or in the foliage. Anthropogenic roosts include buildings, bridges, and mines, among others. Some species of bats are roost specialists and are restricted to only one or few types of roosts; for example, gray bats (*Myotis grisescens*) roost only in caves throughout the year. Other species, in contrast, are generalists, using a variety of roost types at any one time of the year; for example, big brown bats use trees, bridges, and buildings in summer and caves, mines, and buildings in winter.

In the past, most monitoring efforts focused on roosts, and today, roosting habits are still factors to consider when deciding which species or population to monitor. A species that uses only one type of uncommon roost is predictable in time and space, potentially simplifying the monitoring task (e.g., California leaf-nosed bat, *Macrotus californicus,* in geothermally heated mines). In addition, dependency on an uncommon type of roost makes an extreme specialist more susceptible to population declines, thus making monitoring more critical. Species that rely on roosting sites that are common in the environment may be difficult to monitor, even if they “specialize”. For example, hoary bats only roost in the foliage of trees, but potential roost trees often are abundant and widely dispersed across the landscape, making it difficult to locate, let alone monitor, such a species (see also Working Group A, “Over-Dispersed Bats” subgroup report).

At least three aspects of roosting behavior--social grouping, movement among roosts, and intersexual differences--also must be considered when developing monitoring priorities. Some species (e.g., the lasiurines) are solitary, some species form small colonies containing a few hundred individuals or less (e.g., Rafinesque’s big-eared bat, *Corynorhinus rafinesquii*), and other species aggregate in the millions (e.g., Mexican free-tailed bat). A monitoring program may be more successful if based on a species that roosts in moderate-to-large colonies because of the relative ease in detecting such roosts and the fewer sites that need to be monitored. (See also Working Group A, “Colonial Bats” subgroup report.)

Some bats, particularly species that live in trees, tend to change roosts frequently (Lewis 1995). Female Indiana bats (*Myotis sodalis*), for example, change roosts about every three days, and a group of these bats may use more than 17 different trees in a single maternity season (Kurta et al. 1996). Such roost-switching behavior makes the monitoring task extremely difficult because of the unpredictability of the bats in space and time.

To complicate matters even further, males and females of many species often exhibit different roosting behaviors. Adult female little brown bats (*Myotis lucifugus*) typically roost in summer maternity colonies that contain more than 95% females, whereas adult males generally are solitary (Barbour and Davis 1969). If the goal of the monitoring program is to analyze long-term trends for an entire population, then a monitoring procedure that focuses on only one sex may not yield the desired results.

4. Population Status

Bats as a group may rank as the most endangered land mammals in the U.S. (Tuttle 1995), with eight species or subspecies classified as endangered, and others classified as candidates for listing or considered species of concern. Today, population status (i.e., endangered, threatened, etc.) is often the first, and occasionally the only, consideration in prioritizing monitoring and conservation needs. Although convenient, the practice of solely relying on government-designated status to prioritize species for monitoring may not be justified. For example, the gray bat is classified as endangered by the federal government, but it is well on its way to recovery (M. D. Tuttle pers. comm.). Establishing a new monitoring program for this species, simply because it is endangered, may not be warranted. Other species, such as the Indiana bat, may be so imperiled (U.S. Fish and Wildlife Service 1999) that immediate, direct measures are more likely to benefit the species than a long-term monitoring program that may not produce results for years. Finally, a monitoring program may better benefit unlisted species (e.g., small-footed bat, *Myotis leibii*, or red bat, *Lasiurus borealis*), providing data needed to prevent such taxa from becoming listed in the future.

5. Threats

More important than a government-designated status may be the actual threats to continued survival of a species or population. Potential threats to bats may be direct or indirect (Tuttle and Stevenson 1982; Pierson 1998). Direct destruction includes, among other things, hunting for food (Rainey 1998; Wiles et al. 1999), extermination from building roosts (Cope and Hendricks 1970), and wanton killing (Tuttle 1995). Indirect destruction may not be as obvious as direct killing, but for many species, indirect threats potentially have greater impact. Many indirect threats are ecological in nature and relate to water, food, and roosts.

Mining operations indirectly kill bats that drink from leaching ponds containing cyanide (Clark 1991; Clark and Hothem 1991). Changes in water quality impact the prey of bats (Vaughan et al. 1996) and may partly explain decreased species diversity of bats in urban areas (Kurta and Teramino 1992). Pesticides that enter the food chain result indirectly in death or decreased reproductive success (Clark 1981, 1988), and many other chemicals, such as environmental estrogens, may have deleterious, but currently undiscovered, effects on bats (MacLachlan and Arnold 1996). Food chains may be disrupted if foraging habitat is destroyed or modified, leading to a decline in bat populations (Brown et al. 1993, 1995). Reproductive success decreases after maternity colonies are excluded from buildings (Brigham and Fenton 1986), and closure of abandoned mines indirectly causes decreased survival or reproductive success by eliminating maternity and hibernation sites (Tuttle and Taylor 1994). Our purpose is not to list every possible source of mortality (Tuttle and Stevenson 1982; Pierson 1998) but to illustrate the diversity of ways in which bats are affected by human activity. Species or populations with clearly defined threats may be more in need of monitoring programs than other groups.

6. Reality

The feasibility and eventual success of bat-monitoring programs depend on making sound biological choices, having appropriate statistical techniques (see Working Group A report; Sauer 1999), and securing appropriate resources, such as personnel, equipment, and funds. Any monitoring program requires workers in the field, and a program demanding a large number of highly skilled workers may be more difficult to implement than one designed to use volunteers with minimal training (Walsh and Catto 1999). Similarly, technologically simple programs may be less expensive and easier to implement. On the other hand, some projects may have to await the development of technological innovations or new statistical methodology.

Most problems with personnel and equipment may be overcome (at least in theory) by increased levels of funding, but in reality, budgets rarely are adequate. Funding for any monitoring program is influenced by economic factors, legal considerations, and public opinion. Projects with demonstrated effects on agriculture or forestry are more likely to be funded. Legal mandates, such as the Endangered Species Act and the National Environmental Policy Act, can bias which species is monitored and where. Public opinion can influence whether or not private organizations or government agencies will fund a particular program. A positive public attitude also may lead to a greater number of volunteers for a monitoring program, as well as increased donations to private or government agencies that ultimately may sponsor bat-monitoring programs (see Working Group C report). In contrast, negative attitudes, such as those fostered by some public health agencies (Tuttle 1999), may affect the ability to obtain funds or volunteers for any monitoring program dealing with bats. Although, in a perfect world, science should direct priorities, practical considerations (funding, equipment, personnel) are unavoidable.

Concluding Comments

The decision as to which species or population to monitor is complex, and one must consider a range of biological and practical considerations. Unfortunately, there is no single set of guidelines that can be used with every bat community in every part of the country. Specific criteria used to prioritize species for monitoring will depend on the goals of the program, the species involved, and the scale of the program (national vs. local). Monitoring programs are essential for effective conservation and management of bat populations, but the details of any program, including selection of species, must be tailored for each situation.

Working Group C. Existing Information and Programs to Monitor Bat Population Trends: Utility and Coverage of Current Efforts and Potential Expansion in Scale

Working Group Members: Norita Chaney, Alice Chung-MacCoubrey, Rick Clawson, Laura Ellison (Rapporteur), Steve Fancy, Tom O'Shea (Leader), Paul Racey, John Sauer, Allyson Walsh

Overview

Participants submitted a number of issues for consideration under this topic in advance of the workshop. These issues generally fell into four broad categories: organizational and implementation issues, design and analysis issues, programmatic and policy issues, and data management issues. Based on the presentations at the overall meeting and results of the panel discussion, we concluded that expanding use of existing information to estimate bat population trends on a broad scale presents difficult sampling and design challenges that could not be fully explored in the available time. The group instead focused on making recommendations on five issues that are important precursors to consideration of future expanded-scale bat monitoring programs. These issues include: (1) the current lack of organization of existing programs and information on monitoring bat populations in the U.S.; (2) necessary analytical considerations for monitoring bats on an expanded or national scale; (3) lack of a unifying mandate or legislative foundation for bat conservation; (4) promoting public awareness and gaining support for such a mandate (e.g., a National Bat Awareness Week); and (5) optimizing information obtained from marked bats (including existing efforts as well as future studies).

The Working Group recognized the importance of the limited existing information on bat population status, and the value of compiling and synthesizing this information on a national scale in efforts such as the U.S. Geological Survey's Bat Population Database. The group also recognized that although well-designed frameworks for using existing information to measure bat population trends with statistical accuracy and precision have been lacking, there are qualitative historical comparisons, index-based studies, and anecdotal but reliable accounts of declines that provide a strong imperative for bat conservation. Nonetheless, development of more objective and scientifically reliable methods of monitoring trends in bat populations remains an important goal for providing a national perspective on bat conservation needs and successes. The working group also recognized, however, that further advances in technology, statistical design, and funding support would be necessary to create an expanded or national bat monitoring program that can meet this goal.

A network of information flow will be important for stimulating and recognizing such necessary advances, and for communicating information that may be useful in identifying situations needing conservation attention. Thus our first recommendation is the development of a website-based clearinghouse of information on bat conservation-related research. Because bat populations are of significance to agriculture and related segments of the U.S. economy and to national biodiversity, monitoring bat populations is clearly desirable. Therefore our second set of recommendations points out three areas of consideration necessary to establish a scientifically defensible bat population monitoring program: increasing basic ecological information on bats (especially rare species), developing means to estimate detectability at sample sites, and developing appropriate spatial sampling designs (see also Working Group A report). Monitoring bat population trends, however, has no specific national mandate. In a third issue statement, therefore, we call attention to the importance of bat populations in the U.S., the movements of bats across state and international boundaries, and the desirability of establishing formal provisions for bat conservation that can include population monitoring. We highlight legal steps already completed in this regard by many other nations, and provide some initial suggestions regarding the U.S. One such step would be to establish a National Bat Awareness Week to help increase public support for bat conservation, as described in our fourth issue statement. Finally, because much valuable population information can be obtained through properly designed mark and recapture studies (see also Working Group A report), we provide specific recommendations on developing a clearinghouse approach to making technical information on this topic available, and on additional considerations for the design of needed research on marked bats. Our working group did not explore data management issues, one of the four broad categories of issues submitted in advance by participants, because we felt it would be premature to do so pending further advances in the other areas we considered.

Working Group C Issue 1. Lack of Organization of Existing Programs and Information

Issue Description and Rationale

Why is this issue important ? Although the importance of bats to healthy ecosystems is not as well recognized by the general public as it is to scientists, declines in bat populations have been an important concern of resource managers and researchers. However, the breadth of the problem of declining bat populations is not well understood scientifically because current efforts to track declines include a variety of methods and protocols that may lack compatibility and comparability. Considerable information already exists that can assist in identifying data gaps and conservation needs, but this existing information is stored in numerous locations. It is important that researchers and resource managers be aware of existing information and expertise on bat research and monitoring in order to use knowledge that has already been obtained. New funding is difficult to secure, and given that there is no legislative or other mandate for any group or agency to coordinate and fund a nationwide bat monitoring program, it is important to make the most of existing information and to be effective in the use of available funds.

What is generally known about this issue ? Considerable information related to abundance and distribution of bats exists. This information is scattered among numerous organizations in the form of databases and reports, as well as in scientific publications. This and related information such as directories of expertise and sources of local knowledge could be brought together through a clearinghouse (a central source for the organization and distribution of information related to bat populations).

What in general needs to be determined to resolve the critical uncertainties surrounding the *issue ?* A clearinghouse should be developed that solicits and provides information from bat researchers, land management agencies, conservation organizations and others. The information should provide a clear picture of what is known, who is doing the research, and where there are gaps. It should allow users the opportunity to interact and facilitate greater cooperation and collaboration among research scientists and resource managers.

What are the consequences if this issue is not addressed ? General problems with declining bat populations at a landscape or regional scale may not be identified, and bat population declines may occur from which it will take bats many years to recover, with consequent ecological and economic costs. Important data gaps may not be identified if this issue is not addressed, and there will be fewer opportunities for comparing data and adding spatial dimensions to monitoring programs. Interpretation of data (putting site-specific data into context) will be difficult with a lack of communication and information-sharing among various agencies and scientists. Funds may be expended needlessly in duplicating existing information or repeating mistakes made by others. Management agencies may not direct funding optimally if they are unaware of who the subject experts are and the level of existing information.

Means to Resolve the Critical Uncertainties Surrounding the Issue

A web-based clearinghouse should be developed to provide a mechanism for identifying existing information and key individuals and organizations involved in bat conservation and research. Provisions should be made to regularly update the information. The clearinghouse could include the following components:

Directory of Organizations and Individuals in Bat Conservation and Research. This directory would include names, addresses, phone numbers, e-mail addresses and a short description of the role or interest of various organizations and individuals, such as the bat working groups, bat recovery team members, and scientists involved in bat research. The directory would explain the purpose of each of the groups.

Metadata Database. The clearinghouse would not contain actual raw data from various studies, but would give a description of existing data sets and various studies and management efforts that could be searched using keywords. For a particular data set (e.g., exit counts at a particular cave over a 9-year period), the entry in the database would include how the data were collected, the format of the data, where it is stored, and who to contact. The database could also describe current pertinent research projects by summarizing the study objectives, name and contact information for the investigator, scheduled completion dates, and expected products.

Protocol Database. The clearinghouse could provide electronic copies of existing sampling protocols being used for bats, including example data collection forms and recommendations for analyzing and presenting the data. Descriptions of state-of-the-art sampling and analytical methods could also be provided here.

Bat Population Database (BPD). The BPD that is being developed by the U.S. Geological Survey should be part of the clearinghouse.

Searchable Bibliography. References on bats could be added to the database. The clearinghouse could also point to internet resources such as Cambridge Abstract Services, the Institute for Scientific Information and several other indexing sources.

Band or PIT Tag Database. There is no centralized organization for assigning band numbers or PIT tag numbers used on bats, such as the service provided by the U.S. Fish and Wildlife Service for bird banding. The clearinghouse could be used to inform others about ongoing tagging projects and to facilitate exchange of information on marked bats (see Issue 5).

Bat Sound Recording Database. A database linked to the clearinghouse could identify where reference collections and archived records of bat calls are stored.

Other Links. Links to other databases and web sites that contain information pertinent to bat conservation and research (e.g., other agency monitoring programs, weather data, threatened and endangered species databases, Integrated Taxonomic Information System).

Suggestions Regarding Existing Monitoring and Research Programs

Existing monitoring and research programs should strive to identify their activities by participating in an informally linked, web-based clearinghouse. It may be possible to develop and fund portions of the clearinghouse through the U.S. Geological Survey's National Biological Information Infrastructure (NBII). This program already serves similar databases for other natural resources, and the objectives of the clearinghouse fall within the mission of the NBII. Temporarily, the group at the Midcontinent Ecological Science Center may be able to develop a simple prototype to start the clearinghouse on a limited scale. The Integrated Taxonomic Information System (ITIS), an interagency database that provides taxonomic standards for sharing information on species, may help with problems of nomenclature.

Working Group C Issue 2. Analytical Considerations for a National Bat Monitoring Program

Issue Description and Rationale

Changes in bat populations have ramifications for agricultural and forestry segments of the U.S. economy, ecosystem function (including pollination of important vegetation in the American Southwest), and conservation of national biological diversity. Currently, attempts to monitor bat populations are very fragmented, concentrate on just a few species that are endangered or threatened, or involve very local independent efforts. There is need for status information on a wider range of U.S. bat species. For example, in 1994 the U.S. Fish and Wildlife Service named 24 species or subspecies of bats as Category 2 Candidates for listing under the U.S. Endangered Species Act, based largely on an absence of population status and trend information (U.S. Fish and Wildlife Service 1994). These taxa have subsequently been considered “species of concern” since the elimination of Category 2 classifications (U.S. Fish and Wildlife Service 1996).

A clear need exists for bat monitoring programs on a national scale. National level monitoring of bat populations could provide broader perspectives for conservation priorities, prevent duplication of effort, and promote standardized collection of data. Monitoring bat populations on a national scale would help identify bat population changes that may not be detected by scattered and uncoordinated local efforts. Conservation actions in response to local monitoring efforts may not otherwise occur quickly enough to prevent significant widespread losses, whereas establishing that stability or growth in populations is occurring over broad areas may help change priorities when small, local declines are observed.

However, any such program must be properly designed to provide reliable, scientifically defensible information that is more spatially encompassing than results that have been obtained thus far (see also Working Group A, “Colonial Bat Species” subgroup report, Issue 4). There are three major considerations for developing surveys for monitoring bat population trends on a national scale:

- *Needs for basic information on ecology and life history of rare species, and criteria for selecting species to be monitored* (see also Working Group B report).

- *Estimation of detectability at sample sites.* In general, bat studies have not included estimation of detectability when estimating population attributes, but instead have used indices of abundance (see also Working Group A report). Indices do not provide the most reliable data because their accuracy in reflecting the underlying population trends is usually unknown.

- *Spatial sampling.* Studies of U.S. bats, in general, have not adequately sampled the entire population of a species. Instead, surveys typically occur at single (or few) sites and the results cannot be extrapolated to entire populations across a species range.

Why are these sampling issues important ? Although a variety of indices to bat abundance have been proposed, few provide truly reliable information by incorporating methods of estimating detectability. Similar to initial reports of amphibian population changes several years ago, much of the bat population status information is anecdotal or based upon counts or indices that may not reliably reflect the underlying populations. Much of the bat population data are also local, reflecting populations at individual sites without indications of how well these represent regional populations. Consequently, patterns of population change estimated from indices at local sites may not reflect what is truly occurring with the regional population. Because bats migrate, generally have widespread geographic distributions, and pose unique problems for population estimation, a statistically defensible survey must be developed before monitoring can be implemented on a national scale. These programs would have to provide information at geographic scales relevant to managers, such as individual sites, regions, and states.

What is generally known about these issues ? In recent years, a variety of statistical methods have been developed for estimating wildlife abundance, density, survival, and other population parameters. Most of these developments have not yet been applied to bats. Capture-recapture methods in particular provide opportunities for estimation of colony-specific population size, survival, and a variety of other demographic parameters (see also Working Group A report). A number of existing techniques developed for abundance estimation such as distance or multiple observer methods might also allow estimation of bat detectability rates. Large scale surveys of other wildlife, such as the North American Breeding Bird Survey (BBS), provide an enormous amount of information regarding the virtues and flaws of nationwide programs, and the documented deficiencies of these surveys should be avoided in implementation of new monitoring programs. In particular, detectability should be estimated during the survey, sampling frame issues (such as potential biases in estimation associated with roadside counts) can be avoided, and statistical designs such as variable probability sampling or dual-frame sampling can be used to develop cost-effective sampling.

What needs to be determined to resolve the critical uncertainties surrounding the issues ? Spatial sampling schemes need to be developed by exploring alternative designs, including dual-frame sampling and variable probability sampling. Often, these designs will allow complete coverage of important sites, but also provide unbiased estimates from the sampling of less important sites at lesser intensities. Development of appropriate designs will require elaboration of geographic information on sampling frames such as caves or other habitats that can be used to develop strata.

Appropriate population estimation methods are still poorly defined for bats. Development of these methods will require pilot studies over limited numbers of sites and areas to determine feasibility and to obtain pilot data for design of regional scale surveys. Often, collection of ancillary data as covariates will be critical to allow assessment of correlates of changes in survival and population size. These covariates may be at the geographic scale (such as land-use data), or at the local scale (such as roost temperature changes).

Surveys will require considerable planning and design based on an understanding of species life histories and other factors. GIS can be used in designing sampling frames and displaying results such as distribution data. Whenever possible, simplicity should be encouraged to allow maximum acceptance of results, and clarity of presentation should be encouraged while maintaining the ability to answer management questions in a statistically defensible manner.

What are the consequences if the issue is not addressed ? Without development of these surveys, it will be impossible to estimate trends for populations of bats on a regional or national scale.

Means to Resolve the Critical Uncertainties Surrounding the Issue

Before a national-scale bat monitoring program can be developed, advances must be made in methods of enumerating population estimates of bats, beginning at local and colony scales, and these methods need to be applied in an appropriate sampling design. Working Group A has a number of recommendations involving research needs for improving estimation of population size and trend of bats. In addition, for many species of bats in the U.S. and Territories, additional basic natural history and distribution information may be necessary for developing adequate monitoring designs and interpreting results of sampling.

Suggestions Regarding Existing Monitoring and Research Programs

Recognizing the absence of a structured national scheme, the group recommends that ongoing efforts should improve communication and coordination in order to detect broader scale conservation problems. Development of a Worldwide Web-based clearinghouse (as recommended under Issue 1 by this Working Group) should help in this regard, as should efforts to maintain and improve communication among endangered species coordinators and existing networks of informal state and regional bat working groups.

The following suggestions should also be explored to help resolve analytical and sampling issues involved with monitoring bat populations.

- *Ongoing surveys/monitoring programs for bats should be evaluated to determine whether they can provide pilot data for regional surveys*. A variety of surveys exist that provide information on population change for bats. For example, Indiana bats are monitored every two years at certain key hibernacula in Missouri, Indiana, Kentucky, and Illinois. These surveys should be analyzed and critically evaluated. Methods that provide reliable information can be used as models for future survey development for similar species in similar regions. Coordinators of the surveys should be encouraged to publish results in peer-reviewed journals. Information from other programs that have developed well-planned sampling designs and protocols, such as those developed in the U.K. and The Netherlands, should also be evaluated.

- *Detectability issues should be reviewed*. Development of regional surveys that provide reliable data requires that new methods be developed and implemented to estimate detectability at sample sites. New technological tools (including electronic devices in developmental phases and bat detectors which currently are employed only for obtaining index information) should be evaluated as sources of reliable population information. Infrared video recorders should be experimented with to visualize bats recorded by bat detectors. However, pending further developments in acoustic sampling, new efforts at sampling should focus on direct estimation of numbers of bats rather than counting bat echolocation calls. Mist netting should also be evaluated as a source of reliable information on bat populations. Finally, although population estimation may not be feasible using count or index data such as these, species richness may be a useful parameter of interest that can be estimated using count statistics and modern sampling designs (Nichols and Conroy 1996).

- *Sampling frames must be developed that allow variable probability sampling of sites known to be of importance to bat populations of monitoring concern.* Geographic Information Systems (GIS) are useful in summarizing existing information (allowing display of maps of survey points) and should be used in designing sampling frames.

Working Group C Issue 3. Lack of a Unifying Mandate or Legislative Foundation for a National Bat Conservation Program

Issue Description and Rationale

Why is the issue important ? Bats are of tremendous economic importance to U.S. agriculture and forestry. They play important functional roles in ecosystems and are important components of our national biological diversity. Bats migrate across U.S. state and international boundaries. A national program and transboundary agreements among nations neighboring the U.S. are needed to appropriately manage for many U.S. species of bats.

What is generally known about the issue ? Currently there is no formal legal mandate for bat conservation in the U.S. However, there are examples of conservation mandates in Europe and the U.S. that may be used as models and can provide lessons on which to draw. The European Bats Agreement (Agreement on the Conservation of Bats in Europe, London, 1991) under the auspices of the Convention on Migratory Species of Wild Animals, Bonn, 1979, has fostered monitoring of bat populations by some countries. (Although Appendix I to the Bonn Convention identifies the common U.S. migrant *Tadarida brasiliensis* among migratory mammals, the U.S., Mexico, and Canada are not among the 65 parties to this international agreement.) The European Union Habitats and Species Directive addresses both sites and species and also applies to bats. The European Bats Agreement was developed because bats whose ranges and migrations crossed national boundaries were known to be under threat. It has been signed and put in force to various degrees by 13 nations as of this date. The agreement raises consciousness regarding bat conservation and stipulates protection for bats, their roosts, and important feeding areas, but it does not mandate or fund population monitoring of bats. Monitoring is instead carried out independently by the various parties to the agreement. As a result, there are different levels of activity in different countries. The U.K. has the most intense program, and has allocated £ 500,000 to their bat monitoring program over a five-year period. This program uses volunteers to gather data (see Walsh and Catto 1999). The existence of a cadre of volunteers was a significant factor in the decision of the Department of Environment, Transport, and the Regions to allocate this funding. After the initial five-year funding period is concluded, the Statutory Nature Conservation Organizations (England, Scotland, Wales, and N. Ireland) will continue partial funding; partners are being sought to augment these funds. The Netherlands also has an active bat monitoring program that started with an atlas approach. Other European countries have small numbers of personnel devoted to bat monitoring.

The Convention on Biological Diversity (under the Rio Convention) provides that signatory countries obligate themselves to maintain biological diversity. With time this could provide some foundation for bat conservation in the U.S. The U.K., for example, has drafted species action plans under the auspices of this Convention and is seeking corporate sponsorship to underwrite the costs of the plans. The U.S. signed the Convention in 1993 but has not ratified it. Mexico and Canada have both signed and ratified the Convention.

In the U.S., there are two models of long-term wildlife monitoring at a national scale: the Breeding Bird Survey sponsored by the federal government, and the Christmas Bird Count conducted by the Audubon Society. In the U.K., the British Trust for Ornithology also has a volunteer network that carries out annual bird counts. In some schemes, the volunteers pay the Trust an annual fee and, in return, receive newsletters and reports. The British Mammal Society, consisting of both professionals and amateurs, also sponsors surveys.

What in general needs to be done to resolve the critical uncertainties ? Greater consideration should be given to strengthening bat conservation efforts in the U.S. through formal legislation and treaties. Proposals for international conservation of some bat species as transboundary migrants should be supported through the joint U.S.-Mexico-Canada Commission on Environmental Cooperation. Programs should include a component earmarked for in-depth consideration of design and implementation of bat population monitoring.

Several domestic legislative acts and international agreements have elements that could be used as examples or models for drafting national bat conservation legislation. The U.S. Marine Mammal Protection Act of 1972 currently protects pinnipeds, cetaceans, sirenians, sea otters, marine otters, polar bears, and the ecosystems in which these species occur (Baur et al. 1999). Over the years, funding through this mandate has stimulated considerable research in the design and implementation of population monitoring methods for marine mammals. The Migratory Bird Treaty Act also could serve as a model. In the U.K., the Wildlife and Countryside Act protects all species of bats as well as their roosts. No other group receives this level of protection in the U.K. An important benefit of this Act was that it focused attention on two species of horseshoe bat and resulted in censusing of their populations.

Two U.S. initiatives may indirectly provide initial steps towards a national bat monitoring program. Recent legislation and funding for the National Park Service is mandating a monitoring program for biological resources (which can include bats) on National Park Service properties. The Environmental Protection Agency has money in the form of “Star Grants” that can fund regional monitoring programs. These may be sources that could support design and development of pilot bat monitoring projects.

What are the consequences of not addressing the issue ? Reductions in abundance of common species of bats will have economic consequences to agriculture, forestry, and perhaps public health (declines in bats as consumers of insect vectors of disease). Under the current lack of unified efforts and firm mandates, there is also a higher probability of losing rare species of bats before critical knowledge on basic ecology and population status can be gained, particularly in comparison to more common species. Rare species will likely need greater resources to monitor adequately, and thus are at greater risk of being lost before adequate population data can be acquired, given the existing level of resources available to devote to bat conservation. Loss of species or significant populations of bats on the public lands, or of those designated as having special conservation status by resource management agencies, will signal a failure in stewardship.

Means to Resolve the Critical Uncertainties Surrounding the Issue

The Working Group recommends that non-government organizations and other interested parties consider proposing bat conservation programs at a national level, either through support for new legislation and budget initiatives, or through new provisions in existing legislation. Support should also be given for international agreements and ratification of treaties that would include measures for bat conservation. Advantages of formal legislation would include recognition of the importance of bats as part of our national fauna and authorization of funding for bat conservation, aspects of which can involve well-designed programs to monitor bat populations. Professional and scientific societies should be encouraged to support such initiatives. The American Society of Mammalogists should be asked to consider a resolution calling for the development of legislation that would support national bat conservation and monitoring programs. Other professional societies (e.g., The Wildlife Society, the Society for Conservation Biology), museums, conservation groups, and similar organizations and institutions should also be invited to support such initiatives.

Suggestions Regarding Existing Monitoring and Research Programs

Current efforts to monitor bat populations and to improve techniques for estimating bat population trends should be continued and expanded. Ecological monitoring and research programs now concentrating on other biological resources should expand their focus to include bats. As examples: bat conservation on public lands should be a priority for public land management agencies at all levels; the National Science Foundation's Long Term Ecological Research sites should include components related to bat diversity, distribution and abundance; and because the existence and distribution of many species of bats are closely tied to ambient temperatures, monitoring of bat populations and modeling bat population and distribution responses to temperature shifts should be proposed under various global change research programs.

Working Group C Issue 4. National Bat Awareness Week

Issue Description and Rationale

Suggestions have been made by workshop participants and others (e.g., Western Bat Working Group) about designing and implementing a National Bat Survey Week, and there are some ongoing local efforts in this regard. Considering the underlying unresolved analytical issues in measuring bat population trends, the results of such an effort may not at this time provide reliable information. The public and resource managers could easily misunderstand the intent of such activities with raised expectations that reliable bat population monitoring was taking place. However, the idea of a National Bat Awareness Week for conservation education is an excellent concept that would meet part of the underlying motivation for a National Bat Survey Week.

Means to Resolve the Critical Uncertainties

A National Bat Awareness Week could be designed as a period in which press releases about bats are issued, public education programs and lectures are scheduled, and groups are taken to the field by knowledgeable bat biologists. Events could range from group observations of colony emergences at well known sites where disturbance by observers is not of concern (e.g., Carlsbad Caverns National Park, the Congress Avenue Bridge in Austin, the University of Florida Bat House) to echolocation detector demonstrations at evening programs in parks and refuges, and lay groups accompanying bat biologists on netting trips. Such activities and the favorable media attention they would engender could help counter negative images of bats currently being portrayed through the media, and might promote public support for broader mandates for bat conservation.

Suggestions Regarding Existing Monitoring and Research Programs

A National Bat Awareness Week can be promoted as an informal collaboration among many groups, including conservation agencies, non-government organizations and many local groups, schools, libraries, museums and volunteers. With media attention the amount of activity will likely increase substantially over the first few years. Successful examples elsewhere already exist, including European Bat Night, and National Bat Week in England, coordinated by the Bat Conservation Trust. The North American Bat Conservation Partnership (a consortium of interested agencies, non-government organizations, and regional working groups) would be an appropriate umbrella under which such an effort could be initiated.

Working Group C Issue 5. Optimizing Information Obtained from Marked Bats

Issue Description and Rationale

In the past, U.S. bat banding efforts, many of which were large scale and involved many thousands of bats nationwide, were largely uncoordinated and occurred with minimal communication among bat researchers. Negative effects of bands and their application were also unknown at the onset of early bat banding activities. Although these studies obtained previously unavailable and important natural history information about U.S. bats, including gross movement patterns and longevity estimates, they sometimes lacked specific objectives and sampling designs (in some cases mass banding was conducted at certain sites without any subsequent sampling of the area for recaptures.) However, there is now a major subdiscipline in quantitative ecology that allows the more sophisticated estimation of animal population parameters based on well-designed mark-recapture statistical principles (e.g., Thompson et al. 1998; Burnham and Anderson 1999). These new mark-recapture models have yet to be applied thoroughly in studies of bats, but their implementation could lead to important new information critical to monitoring bat population trends (e.g., Entwistle et al. 2000).

Discretion and proper technique in the application of bands or tags must be used when designing and implementing mark-recapture studies of bats. Greater communication between bat researchers is also necessary because bats are highly mobile and likely to move in and out of any given study area. The potential for gaining information from marked bats can be increased by improving the ability of researchers to identify marked bats and to relay recapture information to the original marker. The degree to which such information has been gained from past banding efforts has been limited. For instance, the United States Fish and Wildlife Service (USFWS) served as a clearinghouse for bat banders for several decades. Although hundreds of thousands of bat bands were distributed to researchers over many years, minimal recaptures or recoveries were reported to the USFWS (less than or about 1%). In addition, a moratorium was placed on the use of these aluminum bands on bats in the mid-1970's. Researchers had noticed alarming adverse effects of the bands on some bats and suspected that local population declines were caused by poorly timed banding efforts and band-related injuries. The potentially negative consequences of bands on survivorship and fecundity are reasons to promote discretion in marking bats and to stress proper technique in their application. With indiscriminate marking and lack of communication, the risk of harming individuals and populations is incurred without obtaining the full benefits of mark-recapture efforts based on new statistical theory (e.g., estimates of rates of movements, longevity, survival, effects of management practices and environmental covariates, etc.). Because of the tremendous scientific value of well-designed marked animal studies, we also recommend experimentation with alternative marking techniques, such as PIT tags, that may provide advantages over bands in their application.

Means to Resolve the Critical Uncertainties Surrounding the Issue

Website clearinghouse on marking techniques and existing marked bat studies. A website clearinghouse could serve as a centralized resource, providing information and references on proper bat marking techniques and a means for exchange of marking information. Potential information provided by this website could include a list of contacts (researchers, manufacturers, etc.), a bibliography of related references (e.g., statistical analyses of mark-recapture data, application techniques, and relevant references from other taxa), and a review of mark-recapture practice and theory as they pertain to bats. This review would include information on mark-recapture principles, types of information that can be obtained, proper marking techniques, and the potentially negative impacts of tag/band misuse and poor project planning. A book in preparation tentatively titled, “A practical guide to marking bats” (edited by T. H. Kunz) is an example of the kind of reference that could be highlighted at such a site. This website might also provide a forum for exchange of information on product performance, methods, recent advances in statistical techniques, and other mark-recapture related issues.

A second function of this website would be to serve as a repository for “metadata” on marking projects. From this site, researchers could access information on who has applied marks; where, when, how many, and what types of bands or tags were applied; and what species of bats were marked. (Primary data such as individual tag numbers and attributes of the tagged animals would not be included.) The material provided by this site would be based on the voluntary submission of information by researchers directly to the website, and would perhaps include existing information in the U.S. Geological Survey’s Bat Population Database. Creating a centralized reference site for bat marking projects maximizes the exchange of information that can be gained from band and tag application. This may be particularly useful when recoveries are made by different investigators over long distances or time periods, and when different manufacturers of PIT tags or readers may be involved. The web site could assist bat biologists in avoiding use of duplicate band numbers (or colors) and PIT tag numbers and suggest ways of creating unique identifiers.

Needed Research on Mark-Recapture of Bats. A critical look at the effects of different banding and marking techniques is needed (see also Working Group A report). A study or multiple studies should be designed to investigate the specific effects of different marking techniques, such as PIT tags versus bands or other techniques, and how they impact traits critical to bat population dynamics such as survival and reproduction. This might first be conducted on species that are not as sensitive to disturbance as others and are more common and abundant (i.e., *Myotis lucifugus* or *Eptesicus fuscus*), and might be carried out in a local geographic area with a large network of roosts (i.e., caves, mines, or buildings). This mark-recapture study could also be designed to answer questions about movements, dispersal, environmental effects, management strategies, survival, population size and trend, etc., depending on the study area and other objectives. Determination of the applicability of current mark-recapture techniques to bats should be made in a scientific and repeatable manner.

Additional Considerations. Other issues and questions remain regarding permanent marking of bats in the U.S. Should state and federal agencies be involved in acquiring marking information? Should the use and application of marks to bats be controlled or monitored? If so, by whom? Can useful information still be obtained from past bat banding records ? Is this information worth the expense and effort required to track down or enter historic data (e.g., former USFWS bat banding files) ? Should efforts be made to standardize equipment (e.g., PIT tag readers) ?

Suggestions Regarding Existing Monitoring and Research Programs

In summary, we suggest the following two items regarding the management of existing information and the implementation of programs involving marking of bats: 1) a website clearinghouse for mark-recapture information, and 2) further research focusing on the effects of marking techniques on bat populations. These would help enhance the understanding of bat population biology, thereby improving the ability to monitor bat populations and reduce ecological and economic costs associated with declines that might otherwise be poorly detected.

Literature Cited in Working Group Reports

Altenbach, J. S. 1995. Entering mines to survey bats effectively and safely. Pages 57-61 *in* B. R. Riddle, editor. Inactive mines as bat habitat: guidelines for research, survey, monitoring and mine management in Nevada. Proceedings from a Workshop, Reno, Nevada, January 21-22, 1994. Biological Resources Research Center, University of Nevada, Reno. 148 pp.

Banack, S. A. 1998. Diet selection and resource use by flying foxes (Genus *Pteropus*). Ecology 79:1949-1967.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, KY. 286 pp

Baur, D. C., M. J. Bean, and M. L. Gosliner. 1999. The laws governing marine mammal conservation in the United States. Pages 48-86 *in* Twiss, J. R. Jr. and R. R. Reeves, editors. Conservation and management of marine mammals. Smithsonian Institution Press, Washington, D.C.

Black, H. L. 1974. A north temperate bat community: structure and prey populations. Journal of Mammalogy 55:138-157.

Brigham, R. M., and M. B. Fenton. 1986. The influence of roost closure on the roosting and foraging behaviour of *Eptesicus fuscus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 64:1128-1133.

Brown, P. E., R. Berry and C. Brown. 1993. Foraging behavior of the California leaf-nosed bat, *Macrotus californicus*, as determined by radio-telemetry. Bat Research News 34:104.

Brown, P. E., R. Berry, and C. Brown. 1995. The California leaf-nosed bat (*Macrotus californicus*) and American Girl Mining Joint Venture---impacts and solutions. Pages 54-56 *in* Proceedings VI of the Thorne Ecological Institute: issues and technology in the management of impacted wildlife. Glenwood Springs, CO.

Brownie, C., J. E. Hines, J. D. Nichols, K. H. Pollock, and J. B. Hestbeck. 1993. Capture-recapture studies for multiple strata including non-Markovian transitions. Biometrics 49:1173-1187.

Burnham, K. P., and D. R. Anderson. 1999. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, NY. 353 pp.

Carter, T. C., M. A. Menzel, and D. Saugey. 1999. Population trends of foliage-roosting bats. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

Clark, D. R., Jr. 1981. Bats and environmental contaminants: a review. United States Fish and Wildlife Service, Special Science Report--Wildlife 235:1-27.

------. 1988. Environmental contaminants and the management of bat populations in the United States. U.S. Forest Service General Technical Report 166:409-413.

------. 1991. Bats, cyanide, and gold mining. Bats 9:17-18.

Clark, D. R., and R. L. Hothem. 1991. Mammal mortality at Arizona, California and Nevada gold mines using cyanide extraction. California Fish and Game 77:61-69.

Clark, M. K. 1999. Surveying and monitoring *Corynorhinus rafinesquii* and *Myotis austroriparius* in bottomlands. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

.

Cope, J. B., and D. R. Hendricks. 1970. Status of *Myotis lucifugus* in Indiana. Proceedings of the Indiana Academy of Science 79:470-471.

Dalton, V. M., and D. C. Dalton. 1994. Census protocol for the long-nosed bat (*Leptonycteris curasoae*). Report to Organ Pipe Cactus National Monument, Contract 1443PX866092081. 20 pp.

Eagle, P. C., J. P. Gibbs, and S. Droege. 1999. Power analysis of wildlife monitoring programs: exploring the trade-offs between survey design variables and sample size requirements. http://www.pwrc.usgs.gov/resshow/droege3rs/sa/power.htm

Entwistle, A. C., P. A. Racey, and J. R. Speakman. 2000. Social and population structure of a gleaning bat, *Plecotus auritus*. Journal of Zoology (London). In press.

Fleming, T. H., T. Tibbitts, Y. Petryszyn, and V. Dalton. 1999. Current status of pollinating bats in the southwestern United States. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

Fujita, M. S., and M. D. Tuttle. 1991. Flying foxes (Chiroptera:Pteropodidae): threatened animals of key ecological and economical importance. Conservation Biology 5:455-463.

Gibbs, J. P. 1995. Monitor user's manual. Department of Biology, Yale University, New Haven, CT.

Goodwin, B. J., and L. Fahrig. 1998. Spatial scaling and animal population dynamics. Pages 193-206 *in* D. L. Peterson and V. T. Parker, editors. Ecological scale: theory and applications. Columbia University Press, NY

Hayes, J. P. Submitted. Assumptions and practical considerations in the design and interpretation of echolocation-monitoring studies. *In* W. L. Gannon, M. J. O'Farrell, and W. Bogdanowicz, editors. Echolocation detectors in field studies of bats. Acta Chiropterologica Volume 2.

Hestbeck, J. B., J. D. Nichols, and R. A. Malecki. 1991. Estimates of movement and site fidelity using mark-resight data of wintering Canada geese. Ecology 72: 523-533.

Kunz, T. H., editor. 1988. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C. 533 pp.

Kurta, A., and J. A. Teramino. 1992. Bat community structure in an urban park. Ecography 15:257-261.

Kurta, A., K. J. Williams, and R. Mies. 1996. Ecological, behavioural, and thermal observations of a peripheral population of Indiana bats (*Myotis sodalis*). Pages 102-117, *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and Forests Symposium. Research Branch, Ministry of Forests, Province of British Columbia, Victoria, British Columbia.

Lewis, S. E. 1995. Roost fidelity of bats: a review. Journal of Mammalogy 76:481-496.

MacLachlan, J. A., and S. F. Arnold. 1996. Environmental estrogens. American Scientist 84:452-461.

McCracken, G. F., Y.-F. Lee, J. K. Westbrook, B. B. Balsley, and M. L. Jensen. 1997. High-altitude foraging by Mexican free-tailed bats: vertical profiling using kites and hot air balloons. Bat Research News 38:117.

Navo, K. W. 1995. Guidelines for external surveys of mines for bat roosts. Pages 49-54 in B. R. Riddle, editor. Inactive mines as bat habitat: guidelines for research, survey, monitoring and mine management in Nevada. Proceedings from a Workshop, Reno, Nevada, January 21-22, 1994. Biological Resources Research Center, University of Nevada, Reno. 148 pp.

Nichols, J. D. and M. J. Conroy. 1996. Estimation of species richness. Pages 226-234 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, D.C.

Palmeirim, J. M. and L. Rodrigues. 1995. Dispersal and philopatry in colonial animals: the case of Miniopterus schreibersii. Symposia of the Zoological Society of London 67:219-231.

Pierson, E. D. 1998. Tall trees, deep holes, and scarred landscapes. Conservation biology of North American bats. Pages 309-325 *in* T. H. Kunz and P. A. Racey, editors. Bat biology and conservation. Smithsonian Institution Press, Washington, D.C.

Rainey, W. E. 1995. Tools for low-disturbance monitoring of bat activity. Pages 62-71 in B. R. Riddle, editor. Inactive mines as bat habitat: guidelines for research, survey, monitoring and mine management in Nevada. Proceedings from a Workshop, Reno, Nevada, January 21-22, 1994. Biological Resources Research Center, University of Nevada, Reno. 148 pp.

Rainey, W. E. 1998. Conservation of bats on remote Indo-Pacific islands. Pages 326-341 *in* T. H. Kunz and P. A. Racey, editors. Bat biology and conservation. Smithsonian Institution Press, Washington, D.C.

Ross, A. 1961. Notes on food habits of bats. Journal of Mammalogy 42:66-71.

Sauer, J. R. 1999. A critical look at national monitoring programs for birds and other wildlife species. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

Sheffield, S. R., J. H. Shaw, G. A. Heidt, and L. R. McClenaghan. 1992. Guidelines for the protection of bat roosts. Journal of Mammalogy 73:707-710.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, CA. 365 pp.

Tuttle, M. D. 1976. Population ecology of the gray bat (*Myotis grisescens*): philopatry, timing, and patterns of movement, weight loss during migration, and seasonal adaptive strategies. Occasional Papers of the Museum of Natural History, University of Kansas 54:1-38.

Tuttle, M. D. 1995. Saving North America's beleaguered bats. National Geographic 188:36-57.

______. 1999. Rabies: economics vs. public policy. Bats 17:3-7.

Tuttle, M. D., and D. Stevenson. 1982. Growth and survival of bats. Pages 105-150 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, NY.

Tuttle, M. D., and D. A. R. Taylor. 1994. Bats and mines. Bat Conservation International, Resource Publication, 2:1-41.

United States Fish and Wildlife Service. 1994. 50 CFR Part 17. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species; proposed rule. Federal Register 59(219):58982-59028.

United States Fish and Wildlife Service 1996. 50 CFR Part 17. Endangered and threatened species, plant and animal taxa; proposed rule. Federal Register 61(40):7595-7613.

United States Fish and Wildlife Service. 1999. Agency draft. Indiana bat (*Myotis sodalis*) recovery plan. United States Fish and Wildlife Service, Region 3, Fort Snelling, MN.

Vaughan, N., G. Jones, and S. Harris. 1996. Effects of sewage effluent on the activity of bats (Chiroptera: Vespertilionidae) foraging along rivers. Biological Conservation 78:337-343.

Walsh, A. and C. Catto. 1999. Monitoring bat populations for conservation: the United Kingdom National Bat Monitoring Program. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

Whitaker, J. O., Jr. 1972. Food habits of bats from Indiana. Canadian Journal of Zoology 50:877-883.

Whitaker, J. O., Jr. 1988. Food habits analysis of insectivorous bats. Pages 171-189 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Whitaker, J. O., Jr. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. American Midland Naturalist 134:346-360.

Wiles, G. J., A. P. Brooke, R. C. B. Utzurrum, D. J. Worthington, and W. E. Rainey. 1999. Censusing Pacific island flying foxes: a review of count methods and recent population trends. Paper presented at the Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects. Estes Park, Colorado, 19-23 September. Extended Abstract.

Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster. 1996. Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, D.C. 409 pp.

IV. Extended Abstracts of Presented Papers

Introduction to Bats of the United States

MERLIN D. TUTTLE[1]

[1] Bat Conservation International, P.O. Box 162603, Austin, TX 78716

Four families and forty-five species of bats live in the continental United States. Six are endangered, and 18 have been proposed as candidates for listing. Extreme losses are especially well-documented for gray (*Myotis grisescens*) and Indiana (*Myotis sodalis*) myotis and for the Mexican free-tailed bat (*Tadarida brasiliensis*). Tens of millions of myotis were lost from Mammoth Cave, Kentucky alone in the early 1800's, while the population of some 30 million free-tails from Eagle Creek Cave, Arizona crashed to 30,000 in the 1960's. Even relatively abundant and widespread species, such as the red bat (*Lasiurus borealis*), have declined markedly, though losses have not been quantified.

American bats are extraordinarily diverse and ecologically and economically valuable, though their roles and needs remain largely uninvestigated. Five species of leaf-nosed bats (family Phyllostomidae) are characterized by their unique nose leaves and live primarily along the U.S. border with Mexico. A single species of ghost-faced bat (family Mormoopidae) ranges barely north of the Arizona and Texas borders with Mexico, and five of seven species of free-tailed bats (family Molossidae) are also restricted to southern U.S. border areas. The Mexican free-tailed bat forms the largest colonies of any U.S. species and ranges from Mexico to Oregon in the West, as well as across Texas and the Gulf States to the Carolinas in the East. Thirty-two species of vesper bats (family Vespertilionidae) dominate the continental U.S.

Bats rely on a wide range of echolocation, listening, and visual strategies for navigation and feeding. Extra large ears aid foliage- and ground-feeding bats in listening for insect sounds and are apparently used for low-frequency echolocation by the spotted bat (*Euderma maculatum*). A combination of large ears and eyes enable California leaf-nosed bats (*Macrotus californicus*) to navigate and capture prey without echolocation on all but the darkest nights. Constant-frequency calls commonly emitted by free-tailed bats aid in locating distant prey in open areas well above vegetation, while frequency-modulated calls, which are more often used by vesper bats, provide greater detail when feeding in cluttered environments near the ground or in forest vegetation. Many U.S. bats are far more flexible in their echolocation strategies than previously recognized, some quickly switching between constant-frequency and frequency-modulated calls according to the feeding strategy of the moment.

Bats are the slowest reproducing and longest lived mammals for their size, some having survived for at least 35 years in the wild. Most U.S. vesper bats mate in late summer or fall, ovulating and becoming pregnant in spring. A single young is typically born in June or July, though a few species bear twins, and some members of the genus *Lasiurus* even produce quadruplets. Gestation is variable, depending upon weather conditions and individual behavior that fosters synchronous birthing, especially in cave-dwelling species. Reproductively active females typically enter and leave hibernation first, followed by males and nonreproductive females, especially juveniles, approximately two weeks later. They often migrate separately and also divide into nursery and bachelor colonies while young are reared in summer habitats. Greatest mixing of sexes and ages occurs in late summer after nursery colonies break up, and segregation among sex and age groups is greatly reduced.

Bats are extremely loyal to traditional areas of both summer and winter habitat. Most leaf-nosed and free-tailed bats migrate south in fall and remain active year-round, while most vesper bats migrate to special cold-air trapping caves, mines, or cliff-face crevices to overwinter in hibernation. A few vesper bats migrate south, then burrow into leaf litter or dense grass to hibernate in relatively mild climates. Most bats appear to be extremely loyal to specific summer and winter sites, though a single summer colony territory may include multiple caves over hundreds of square miles of habitat.

Roosting behavior varies widely among species, as well as within species populations occupying different climates or habitats. Fewer than six species require caves year-round, though most rely on caves to varying degrees in winter. Species that are most reliant on caves form the largest and must vulnerable aggregations and are the most often disturbed, vandalized, and endangered. However, because non-cave-dwelling bats can be extremely difficult to monitor, their declines remain largely undocumented. In contrast to cave-dwellers that sometimes form nursery colonies of thousands or even millions of individuals, other bats normally gather in groups of only dozens to hundreds and often are difficult to find.

Most U.S. species roost in tree cavities, such as woodpecker holes, lightening strike crevices, hollows resulting from decay or fire, or behind loose bark, typically in the largest old-growth snags. Especially in the West, cliff-face and other rock crevices are especially important as roosts, though only a very small proportion provide suitable temperatures or safety from predators. A few bats, especially of the genus *Lasiurus*, roost in tree foliage. Many species have adapted to artificial roosts, including in buildings, bridges, mines, and bat houses. They frequently switch roosts, and rapidly learn to avoid capture, thus greatly complicating long-term monitoring.

Available evidence suggests that the most precipitous loss of large bat populations likely occurred early in the last century, with additional extensive losses in the 1970's, precipitated by grossly exaggerated rabies claims. For many species, it is now impossible to document early losses, though stains and guano deposits in limestone caves validate early reports of enormous populations in caves such as Mammoth Cave, Kentucky.

In 1972, North American bat biologists became alarmed by well-documented losses of bats that were occurring at that time, especially among cave-dwelling species. They attempted to gain public and governmental support for bat conservation. However, their efforts were rendered largely ineffectual by public health and pest control officials who inundated the news media with misleading, often false, stories designed to frighten the public regarding bats as sources of rabies.

Today, the public is far more aware of bat values and is supportive of bat conservation efforts, leading to many new opportunities for progress, though misleading statements about rabies continue to disseminate misinformation that remains an extreme threat. Although by far the most serious bat declines appear already to have occurred, monitoring of remaining populations is essential to gaining support, to setting priorities, and to evaluating success.

Methods for Estimating Numbers of Bats: Challenges, Problems, and Sampling Biases

THOMAS H. KUNZ[1]

[1]Department of Biology, Boston University, Boston, Massachusetts 02215

Methods used for estimating numbers of bats will vary depending on the size and mobility of the species, investigator access to roosting sites, availability and applicability of electronic devices for censusing, and the relative numbers of individuals present. A good basic knowledge of the species to be studied is important before choosing one or more methods. This includes prior knowledge of roosting habits, foraging behavior, seasonal movements, and how environmental factors may affect local abundance. Knowledge of historical and temporal-spatial patterns associated with a particular species or population may also be important. When binoculars, night-vision devices, infrared imaging devices, or ultrasonic bat detectors are used to extend the sensory capabilities of the observer, investigators should be thoroughly familiar with the operation of these devices before they are used in the field, and understand their detection limits and potential biases. Roost sites of species that are relatively easy to locate and that house small to moderate-size aggregations offer the greatest potential for estimating numbers present. Species that roost alone or in small groups in foliage, rock crevices, and tree cavities, and gregarious species that form exceptionally large populations pose the greatest challenges for censusing.

Depending on the species and roosting situation, bats may be censused while they are in their roosts, or in flight while emerging, commuting or foraging. Historically, three observational methods have been used for censusing bats. These include roost counts, disturbance counts, and nightly emergence counts. Estimating the number of bats present in roosting situations is seldom feasible except for some relatively small, gregarious species. Some species are highly susceptible to disturbance in roosting situations, and may abandon the site at certain times of year. In situations where direct access to the interior of a roost site is not practical for making direct counts, nightly emergence counts generally offer the best alternatives for estimating numbers of bats present. In some situations, estimates of relative abundance may be the only type of data that can be obtained using a reasonable amount of effort and time, for species that are solitary or roost in small groups.

Estimating the number of megachiropterans that roost in trees sometimes can be accomplished by stationing observers at specified positions to insure unobstructed views of roosting bats. The visibility of the bats and the experience of the observers will largely influence the reliability of estimates. Reliability of diurnal roost counts generally decreases with increasing numbers of bats present, reflecting the extent to which direct observations are limited by dense foliage. Use of binoculars and low-light level video cameras may facilitate reliable roost counts in some situations.

Estimating the numbers of microchiropterans present in roosts pose considerable challenges, largely because of the wide range of roosting habits. Species that form large roosting aggregations in caves, mines, buildings, and similar structures, sometimes numbering upwards to several million individuals, pose a major challenge for censusing. Species that roost alone or in small groups in dense foliage, in rock crevices, and in tree cavities pose other sorts of challenges. In any event, methods used to census bats in roosting situations should be designed to minimize disturbance and sample biases.

For many species it may be necessary to use a combination of observational and capture methods to obtain accurate census data. In some roosting situations, where a species forms small, compact, conspicuous clusters, direct visual counts may be possible. In other situations, an observer may be able to estimate the number of lactating females present by counting the number of non-volant pups present after adults depart at night to forage. Assuming that all females give birth, and the number of lactating females equals the number of young present, then an estimate of the number of females present in the colony can be made. Some bat species leave stains from secretions of skin glands and deposition of urine on roost substrates, and sometimes it is possible to make very crude population estimates using this information. At best, the latter method can be used for trend analysis of bat populations. It may be possible to estimate colony size by measuring the area on the floor of a cave or other roost site covered by fresh guano deposits, and multiplying this area by the cluster density of roosting bats. Estimates of cluster density and spatial coverage of bats, however, poses the greatest challenges because of irregularities of the roost substrate, and the roosting bats may be distributed in several layers. Moreover, estimating cluster density and spatial coverage could be disturbing to roosting bats, especially during the maternity period when pups are present.

Emergence counts of bats that depart nightly from caves, mines, tree cavities, and buildings can be one of the most effective ways to estimate the number bats occupying such sites. Such counts are especially effective for estimating the numbers of bats that roost in inaccessible places, such as mines and caves that may be unsafe to enter, or where entry by one or more observers may cause disturbance to the bats. Ideally, emergence counts should be made repeatedly over several weeks to establish intra-colony variation in the number of bats present. If limited time is available, two census periods are recommended--one before young are volant (maximum adult population) and another after they become volant (adult and young population).

The number of observers required to conduct emergence counts will depend on the size and configuration of the roost openings, the number of openings from which bats exit, and the relative number of bats present. Observers are assigned specific exits or fields of view, and should be present at their stations before the onset of emergence to ensure that the earliest departing bats are counted. Emergence counts may underestimate the number of bats present, especially if some individuals delay emergence (e.g., lactating females), or they emerge well after dark (e.g., young of the year). Infrared thermal imaging, coupled with computer analysis of data, is a potentially important census method, because infrared images of emerging bats can be recorded independent of the background (day or night). Infrared thermal technology may be the most important and reliable method for censusing bats in colonies that range in the thousands and millions. Notwithstanding, the high cost of infrared thermal imaging may prohibit its general use.

An obvious advantage of electronic and computer-based devices used to census bats is that these methods can be used in the absence of an observer, thus yielding repeated records over extended periods. Notwithstanding, devices used for electronic censusing must be consistently maintained in excellent working condition, and a reliable power supply is essential. Infrared videography and electronic or mechanical counting devices have been used successfully in some situations to count emerging bats, and these methods offer less expensive alternatives to infrared thermal imaging.

Nightly dispersal counts have been used successfully to estimate numbers of megachiropterans present. As bats emerge from their diurnal roosts, counts can sometimes be made by silhouetting individuals against an unobstructed sky. Two or more observers should be positioned at designated stations at least one hour before nightfall, and should count only those bats that depart within a pre-assigned arc surrounding the roost. Use of light-gathering binoculars should facilitate counting, although decreasing light levels at the time of nightly dispersal may reduce visibility.

Disturbance counts have been used with limited success at roosts occupied by some gregarious megachiropterans. Successful counts require a minimum of two observers. One person enters the roost area and disturbs the bats by making loud noises, while the other individuals count the bats as they take flight. Assuming that all bats in the colony take flight, individuals may be counted directly or photographed with a camera fitted with a wide-angle lens. The success of a disturbance count depends on several factors, including the relative sensitivity of bats to disturbance, the skill of the individuals causing the disturbance, whether all bats simultaneously take flight, and the position of the photographer relative to the flying bats. Because some large megachiropterans are known to habituate to extraneous noises, the reliability of this method for estimating the numbers of bats remains unclear.

Estimating the number of foliage-, crevice-, and cavity-roosting bats also pose special challenges. Available methods are often limited to randomly searching for expected roosting sites, but this approach is very labor intensive and unproductive. Radiotelemetry is a valuable technique for locating roosting sites of some species. Once roost sites are located with radiotelemetry, emergence counts may be possible using visual counts, photography, videography, or infrared thermal imaging.

Estimates of the numbers of bats present in hibernacula pose several challenges, including access to the bats for censusing, physical complexity of hibernacula, potential for disturbing hibernating bats, and safety considerations. For making comparisons over several years, hibernating bats should be censused in mid-winter when the populations are at peak density, and visits should be limited to once every other year. Safety considerations and the size and complexity of the hibernaculum will dictate the number of personnel needed to conduct a census in caves and mines. Depending on the expected number of bats present, the team should minimize the amount of time spend conducting the census to avoid causing a bats to arouse. Estimates of the numbers of solitary species, and those that roost in small, discrete clusters can often be made by enumerating the numbers present. However, for species that form large dense aggregations, numbers may be estimated by determining the cluster density at selected sites, and then extrapolating these numbers to the total area of the roost substrate covered by bats. Identification of species based on visual assessment, rather than handling each bat, is needed to avoid disturbance.

Foraging and commuting bats pose special challenges for assessing the numbers of individuals present in a given habitat. Most bats are difficult to identify and census as they fly at night--although some species have distinct flight patterns and may be identified with some degree of confidence. An estimate of relative numbers may be the most one could expect from censusing bats in flight as they forage. Estimating relative numbers of flying bats present in an area can be facilitated by deploying one or more of the following devices: mist nets, harp traps, night vision devices, infrared cameras, infrared thermal imaging devices, and ultrasonic detectors (for echolocating bats). In regions where echolocating bats are known to commute and forage, ultrasonic bat detectors may be important for identifying some species, and valuable for estimating their relative abundance. Learning to distinguish different bat species by their echolocation calls requires considerable practice, good acoustic memory, and lots of patience. With patience and practice, species-specific characteristics of echolocation calls, including frequency composition, changes in frequency with time, and duration of pulse repetition rate, may allow an observer to identify several species of bats present in a given area. However, a few species of bats, notably those that glean arthropod prey from surfaces, typically produce low intensity calls and may not be detectable with bat detectors.

Ultrasonic bat detectors have been used with varied success to determine the presence and relative abundance of bats. Most genera and many bat species differ in the frequency span, duration or shape of their cruising echolocation calls. The ability of bat detectors to discriminate between closely related taxa will vary with the type of detector and the experience and skill of the observer. Quantitative methods for identifying echolocating species in the field are preferable to qualitative methods. Use of bat detectors requires a minimal knowledge of electronics, a thorough knowledge of echolocation, bioacoustics, and methods of sound analysis.

Suggested References

Barclay, R. M. R., and G. P. Bell. 1988. Marking and observational techniques. Pages 59-76 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Jones, C., W. J. McShea, M. J. Conroy, and T. H. Kunz. 1996. Capturing mammals. Pages 115-155 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, D.C.

Kunz, T. H., and A. Kurta. 1988. Capture methods and holding devices. Pages 1-30 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Kunz, T. H., D. W. Thomas, G. C. Richards, C. R. Tidemann, E. D. Pierson, and P. A. Racey. 1996. Observational techniques. Pages 105-114 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, D.C.

Mitchell-Jones, A. J. 1987. Survey and monitoring. Pages 12-16 *in* A. J. Mitchell-Jones, editor. The bat worker's manual. Nature Conservancy Council, Interpretative Services Branch, United Kingdom

Thomas, D. W., and R. K. LaVal. 1988. Survey and census methods. Pages 77-89 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Thomas, D. W., and S. D. West. 1989. Wildlife habitat relationships: sampling methods for bats. General Technical Report, PNW-GTR-243, U.S. Forest Service, General Technical Report, Pacific Northwest No. 243, Portland, Oregon.

Monitoring Bat Populations for Conservation: The United Kingdom National Bat Monitoring Program

ALLYSON WALSH[1] and COLIN CATTO[1]

[1] The Bat Conservation Trust, 15 Cloisters House, 8 Battersea Park Road, London, SW8 4 BG.

Introduction. Effective bat conservation relies on population monitoring information to identify changes that are of conservation concern at a sufficiently early stage. In the UK, a paucity of historical data on bat population sizes means that population trends have been difficult to evaluate to date. Funded by the UK government, The Bat Conservation Trust is running a five-year research program to develop monitoring procedures for target bat species and to assess how these (or other) techniques could be applied to the remainder of the UK species (of which we have 16). The program is designed to help meet obligations to the conservation of bats under national legislation and international agreements to which the UK is party. It is expected to provide data of value to broader conservation actions and policy development and implementation. In this paper we review the history of bat population monitoring efforts in the UK and the development of the UK National Bat Monitoring Programme (NBMP). We set out the goals and objectives of the program, the organizational structure, and the field methods being implemented for target species. Monitoring projects typically involve a large number of sites that are surveyed annually during some period of time, and in practice identifying trends with confidence can be difficult if survey design and formal sampling strategies are not considered right at the start. We therefore outline our development of a formal sampling strategy for the NBMP and present results of power analyses that give pointers to the most appropriate sampling design for making reliable inferences about population trends. Although there are obvious difficulties in monitoring bats, it is considered essential to improve techniques and establish a sustainable bat species monitoring program that will contribute to UK bat and wider conservation interests.

History of Bat Population Monitoring in UK and The Development of the National Bat Monitoring Programme. All the commoner UK bats appear to have suffered declining populations in recent decades. About half the species are rare, two (greater and lesser horseshoe bats) are endangered and one (mouse-eared bat) has already become extinct in the UK. Several others are so elusive (barbastelle) or difficult to distinguish from others (Brandt's from whiskered; grey long-eared from brown long-eared) that little can be said about their status and ecology. Historically, efforts to track bat populations in the UK have concentrated on three species in particular; the greater and lesser horseshoe bat and the pipistrelle bat (now split into two species - herein *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*). The greater horseshoe bat population has received the most attention from naturalists, probably because the species is localized, conspicuous and faithful to specific sites in winter and summer. Detailed counts have been made of ringed animals in capture/mark/recapture studies at hibernacula since the 1940's and also at summer roosts since the 1960's. These counts have been made by different naturalists at localized geographical sites within the species range (Hooper 1983; Stebbings and Arnold 1987; Ransome 1989). The data have not been compiled to examine trends collectively for the

UK, and while a similar decline was identified in all areas between 1950 and 1980, counts over the past twenty years indicate declines in populations in some areas and increases at others. The lesser horseshoe bat has also been counted reasonably systematically both in winter and summer roosts, but data collected using different techniques and by different naturalists in different localized areas have given a conflicting picture. Based on summer maternity colony counts at 36 roosts in England and Wales, R.E. Stebbings estimated that in the seven years up to 1992 there had been an overall size reduction of 12%, while data collected by G. Jones at hibernacula in south-west England suggest a population increase (Harris et al. 1995). In order to determine precisely how population levels are changing in this species, a project to monitor maternity colonies in Wales was set up and funded by the Countryside Council for Wales (CCW) in 1993. This project evaluated counting methods in detail and the findings are currently being used by NBMP to develop maternity colony monitoring projects for this and other species across the UK. Collaboration with CCW has resulted in consistent methods applied across the UK and data from the project are fed into the NBMP. Although it is still common and widespread, pipistrelle population levels were estimated by the National Bat Colony Survey project to have fallen by 62% between 1978 and 1987 (Stebbings 1988). A more recent re-analysis of the data using a more appropriate baseline figure than was used by Stebbings suggests that 1987 levels were 79% of those in 1980 and that the downward trend has continued, with 1992 population levels estimated to be 56% of 1980 levels (Harris et al. 1995). The National Bat Colony Survey started in 1978 and is still running in parallel with the NBMP. It involves householders throughout Britain who make emergence counts of bats at nursery colonies in mid-summer. The collection of data is funded privately and the data held by a private consultant, R.E. Stebbings. The protocol for the project provided the basis of the method used by the lesser horseshoe bat monitoring project in Wales and now by the NBMP. There appears to be little information upon which to base population estimates or estimates of trends for any of the other species in the UK.

To summarize, despite the best efforts of many committed naturalists and biologists providing data on localized populations of bats, there has been no structured national system for monitoring bats in the UK. A national monitoring system is needed to answer ecological questions about populations, and because answers to these questions will aid bat conservation decision-making processes. As well as by domestic legislation, bats are protected in the UK under several international Conventions, Directives or Agreements. These have been a major stimulus to develop and adopt a national monitoring strategy for bat populations. The Bern Convention[1] was translated into UK domestic legislation through the Wildlife & Countryside Act 1981. The protection of bats under this Act led to an increase in public interest and concern in bats and greater resources for bat conservation becoming available. Since 1982, local Bat Groups, composed of amateur enthusiasts, have been formed in most counties in the UK. Their primary aim is to promote bat conservation action, and The Bat Conservation Trust acts as an umbrella organization for the local bat groups (currently numbering 95). Such a structure was recognized as a valuable framework to enable large-scale national surveys and the first three-year national bat habitat survey was funded by the Joint Nature Conservation Committee in 1990. The National Bats and Habitats Survey (NBHS) (Walsh et al. 1995; Walsh and Harris 1996a, 1996b) provided data on habitat preferences and abundance of bats in the UK. The project arose primarily in response to the European Union Habitats and Species Directive[2], which is concerned with the designation of conservation areas and maintenance and restoration of favourable conservation status" for certain bat species. The NBHS was an important trial because it showed the practicality of volunteers carrying out bat counts within randomly selected survey squares in the UK. In 1994, the UK signed the Agreement on the Conservation of Bats in Europe. The Agreement was set up under the Bonn Convention[3] which recognizes that endangered migratory species can be properly protected only if conservation activities are carried out over the entire migratory range of the species. Obligations to the Agreement include to identify and protect important sites for bat conservation and to work in co-operation towards developing consistent bat monitoring strategies. Implementation of obligations under this Agreement led to the UK Government's decision to fund a National Bat Monitoring Program.

Program Funding and Timescale. The Bat Conservation Trust (BCT) secured 100% funding to run the program in early 1996 as a five-year contract for the Department of the Environment, Transport and Regions (DETR). Funding by the DETR will end with year 2000, at which point monitoring obligations pass to the devolved statutory nature conservation organizations; English Nature, Scottish Natural Heritage, Countryside Council for Wales and The Environment and Heritage Service (Northern Ireland). It is anticipated that a significant amount of core funding will come from these sources, but to reach 100% funding, BCT will need to seek partnerships with other organizations and agencies; possible partners include the Environment Agency, Forestry Authority and Ministry of Agriculture, Food and Fisheries. It is considered that in the long-term, funding from a diverse number of sponsors will be a more stable support system than reliance on a single sponsor.

In Europe there is only a single example of a similar monitoring project. In 1995, the Dutch Mammal Monitoring Project (Zoogdiermonitoring) was started by the Dutch Mammal Society (VZZ). The project was initially funded by the National Statistical Service and Ministry of Agriculture, Nature Management and Fisheries. The aims of the project are to develop an early warning system to detect factors affecting mammal populations and field work is carried out by a mix of volunteers and professionals, but the mix is weighted towards professional input. Bat monitoring initiatives underway in 1996 included winter counts of hibernating bats, counts of maternity colonies, transect counts of advertising male bats and transect counts of passing bats (mixed species). No formal sampling strategy is followed by the scheme. The scheme had a set back one and a half years ago when financial support from the government was withdrawn from the bat detector based schemes. This was due mainly to a lack of voluntary participants in the surveys. The society failed to find additional financial support needed to buy in professional input to the bat detector surveys, with the result that they have been discontinued. Roost and hibernation site monitoring is continuing with government support.

Program Goal and Objectives. The goal in setting up the NBMP is to develop a statistically defensible program to monitor populations of all resident species of bat in the UK.

The specific objectives are:

To set out a long-term strategy for the monitoring of the 16 resident species of bat found in the UK and outline monitoring methodology options for each species.

To develop in detail and implement monitoring schemes for target species which have populations of a sufficient size to provide reasonable data from a countrywide survey involving volunteer participation.

To obtain baseline monitoring data and improved distribution maps for each selected species that can be used to analyze the ecological determinants of the distribution and abundance of bat species.

The NBMP will provide precise information on long-term changes in population levels for a representative selection of our commoner bats across the range of regions and habitats in the UK. A key long-term objective will be to identify any rapid declines in species that require conservation action, and in combination with other programs and strategic land use monitoring data, to provide pointers as to the causes of population changes. In a wider context, the NBMP aims to promote bat conservation through a unique partnership of large numbers of skilled volunteers and a small number of professional staff at BCT. The result will be good quality monitoring information collected in a highly cost-effective manner.

Geographical Scope, Species and Field Survey Methods. The geographical range of the monitoring program is the whole of the UK; England, Wales, Scotland and Northern Ireland. Eight target species of bat are included in the program: lesser horseshoe (*Rhinolophus hipposideros*), greater horseshoe (*Rhinolophus ferrumequinum*), serotine (*Eptesicus serotinus*), noctule (*Nyctalus noctula*), Natterer's (*Myotis nattereri*), Daubenton's (*Myotis daubentoni*), *P. pipistrellus* and *P. pygmaeus*. These were chosen because of conservation concern, because they constitute a representative range of different feeding and habitat selection strategists and because they have populations of sufficient size to provide reasonable data for countrywide surveys.

For long-term success, the program requires reliable methods of obtaining adequate data that balance disturbance to animals, survey effort and cost and geographical coverage. Three basic approaches were identified as suitable large-scale survey techniques: observations in hibernation sites, observations at maternity colony roost sites, field survey with the use of bat detectors. Other techniques being investigated in Europe include the use of male mating territories (the Netherlands) and faunal diversity at hot spots (Scandinavia).

Summer Maternity Colony Counts are conducted in June, just prior to average parturition dates when the numbers of bats in the colony roost sites are more stable and provide a more repeatable estimate of colony size. Two counts are made of bats as they emerge from known roost sites. Site selection is volunteer driven. Species for which this method is viable are the greater and lesser horseshoe bats, *P. pipistrellus*, *P. pygmaeus*, serotine, noctule and possibly Daubenton's and Natterer's bats. Schemes for pipistrelle, serotine and lesser horseshoe bats are currently in place. Schemes for Daubenton's and Natterer's bats are at the trial stage.

Summer Bat Detector Surveys. These surveys are conducted in July and August. Methods use a combination of transect walks and spot counts within stratified-randomly selected 1 km square areas. Species for which this method is viable are *P. pipistrellus, P. pygmaeus*, Daubenton's, serotine and noctule. Two schemes are currently in place. The "NSP Survey" is a mixed species survey of noctule, serotine, *P. pipistrellus* and *P. pygmaeus*. Surveyors walk a pre-determined triangular transect route across an allocated 1 km square area on two evenings during July. Noctule and serotine bats are recorded while walking with the bat detector tuned to 25 kHz, and pipistrelle 45/55 kHz bats are recorded at 12 pre-determined stopping points along the route, with the detector tuned to 50 kHz. The "Daubenton's survey" is a single species survey which focuses on waterways given the riparian nature of this species. Surveyors walk a 1 km transect route along an allocated waterway site on two evenings during August. They record Daubenton's bats at 10 equally spaced stopping points along their route.

Winter Hibernation Site Counts are conducted in January and February when temperatures in the UK are generally at their coolest and most stable. Surveyors make two surveys of the site and require a license issued by the relevant body to enter sites. This limits the number of participants in this scheme. Species for which this method are viable are the greater and lesser horseshoe, Daubenton's and Natterer's bats.

Additional data collected includes information on the structure and type of site, information on the habitat types present/absent at the site and for each evening survey, information about general weather conditions and bat detector equipment used. All three techniques have their drawbacks, either through the nature of the bats themselves, through exogenous factors that influence bat behavior or through current skill levels of those undertaking monitoring. To strengthen conclusions and evaluate strategies, target bat species were chosen where at least two strategies were felt to be viable, and a rolling program was initiated to incorporate pilot studies and baseline surveys for all selected species and methods. Baseline data are collected over a consecutive two-year period. Further to this, a variety of verification projects are being undertaken by project staff and a small group of highly trained and experienced volunteers. These are examining aspects of each technique such as roost formation/loss, observer variation in recording bats, and species identification accuracy.

Organization and The Use of Volunteers. Two full-time members of staff are employed to run the NBMP: a Project Coordinator and a Senior Field Officer. Temporary office assistance and professional field assistance is contracted on a seasonal basis. The majority of NBMP field work is carried out by skilled amateurs across the country. Allocation of survey sites and the mailing of survey forms are controlled centrally from the BCT office. We acknowledge safe receipt of NBMP forms directly with observers when they reach the BCT office. In early spring each year everyone taking part receives a copy of the program's annual newsletter *Bat Monitoring Post*. News of the surveys is also reported in a regular column and occasional articles in *Bat News*, the BCT's quarterly newsletter. While the greater part of the NBMP field work is carried out by volunteers, we recognize that the skewed population distribution towards the south and east of Britain necessitates the funding of professional field workers to cover gaps in remote regions. Wherever possible we try to employ field workers in situ to reduce costs.

The UK is fortunate in having a reservoir of bat expertise throughout the country that is focused in local groups, and the majority of active volunteers are members recruited from local groups. Volunteers are also sought through leaflet distribution, talks, workshops, wildlife magazine articles and newsletters. A major thrust of the program is to raise skill levels amongst volunteers through training. We run-one day bat identification workshops for beginners and more advanced training workshops introducing time expansion techniques. We are currently developing a standard workshop pack including a CD of sounds.

Survey Design and Sampling Strategies. The broad aim, in devising a monitoring program for bats in the UK, is to provide precise information on population changes. In doing this, bat populations need to be sampled in such a way that biologically important trends can be detected with an acceptable level of confidence. Often in biological monitoring projects, sources of "noise" in counts may obscure the "signal" associated with ongoing trends and so proper attention to statistical aspects of survey design and sampling strategy is needed. In designing surveys for the NBMP, our start point was to apply a general sampling strategy developed from the results of a previous survey of bat abundance across the UK, and then to optimize the design for individual species and schemes where appropriate. At the very beginning of the contract in 1996, a technical meeting was held with population statisticians and a short report contracted to advise on potential strategies for a national bat monitoring scheme. Once some data had been collected by the survey schemes, we evaluated different sampling designs in more detail using power analysis. Two key points from the assessment should be mentioned. First, colony counts are effective for monitoring change if nearly all colonies are known and monitored, or if it is rare for new colonies to be established and a representative sample of colonies is monitored. Thus they will not give reliable estimates of trends for more mobile species. The methods are fundamentally biased because they fail to measure the contribution to change of newly established colonies. A randomized survey of potential roost sites in bounded areas would allow this component to be measured but may prove impractical. Second, given good design and training, simple counts of bat passes by species from randomized transect or spot count surveys using bat detectors will yield estimates of relative abundance by species and hence estimates of trends in numbers. However we must be aware of the following caveats; there should be no trend over time in the sensitivity of the equipment or in detectability of bats, detected passes should be reliably identified, alternatively a proportion of passes should be identifiable and there should be no trend over time in this proportion.

Selection of Sites. Statistically greater precision is achieved with a large number of randomly selected smaller sampling units than with a small number of large units, and stratifying the sample provides a more efficient strategy than simple random sampling (see Cochran 1977). For the field monitoring schemes, the 1 km square was selected as a convenient sampling unit and the land classification scheme developed by the Institute of Terrestrial Ecology, UK, was selected as an appropriate stratification system. The land classification system assigns every 1km square in Britain to one of 32 land classes. Squares in each land class have similar climate, physiogeography and pattern of land use (Bunce et al. 1996). In a previous national survey of bat abundance (Walsh and Harris 1996a, 1996b), land class was found to be a significant factor influencing abundance, and thus appeared a sensible choice of strata. Using the variance in the abundance data for each land class an optimal allocation of sites between land classes was calculated and in allocating sites to volunteers we attempted to adhere to this structure. In the case of roost and hibernation sites, stratification by land class is post-hoc.

Sample Size and Power. To assess the probability that population changes of a given magnitude will be detected under differing sampling designs, power analyses were carried out using three sets of data: pipistrelle roost counts (roosts of both *P. pipsistrellus* and *P. pygmaeus* combined) collected at a total of 412 roosts over two years (1997,1998), lesser horseshoe bat roost counts collected over five years (1993-1997), and transect survey data of Daubenton's bat passes collected over two years (1997, 1998). Log transformed count data were analyzed using REML - Residual Maximum Likelihood - (Robinson 1987) in order to estimate the different sources of variability in the data. These variabilities were then used to construct a large number of simulated datasets with similar patterns of variation to the real data, but with differing numbers of sites (50,100,200,400) and different numbers and permutations of years surveyed. Datasets were initially simulated without any year-to-year variation and then a number of trends were added (2%, 3% and 5% declines per year on the untransformed scale). Two hundred simulations were used for each combination of factors and population trends were examined using a simplified version of the "route regression" approach (see for example James et al. 1996). All sites were weighted equally and two-sided tests were used. The power figures gained by this analysis are discussed as the percentage of simulations that produced a statistically-significant trend estimate at $P < 0.05$. Results for the roost counts of lesser horseshoe bats were encouraging. With a sample size of 100 sites, the scheme will have a 100% chance of detecting a decline from 3-5% over 10 years. Over a period of five years this would be reduced to 94 % to detect a 5% decline, 56 % to detect a 3% decline and 32% to detect a 2% decline. The results for transect survey counts for Daubenton's bats show a similar pattern of power The results for the pipistrelle are less encouraging, as was predicted for a more mobile species. With a sample size of 200 sites, the scheme will have a 100% chance of detecting a 5% decline, a 92% chance of detecting a 3% decline and a 57% chance of detecting a 2% decline, over 10 years. Over a period of five years this would drop 48 % for a 5% decline, 20% for a 3% decline and 9% for a 2% decline. A larger sample size of 400 sites within the scheme would improve matters yielding an 100% chance of detecting a 5% decline over 10 years and an 80% chance of detecting an equivalent decline in five years. It is therefore likely that a run of 10 years data will be needed before what we estimate to be a medium to steep decline of pipistrelle bats can be identified with confidence. Please note that a 5% decline would reduce a population of 100 bats to circa 77 over 5 years and 60 over 10 years. Real figures for pipistrelle bats estimated from maternity colony counts over a five-year period (1980-1985) give a reduction from 100 to 76.4 and over a ten-year period (1980-1990) from 100 to 68.8 (Harris et al. 1995) and thus a real estimate of decline for this period is slightly under 5%. Power figures for the schemes are therefore based on a realistic and possibly a conservative rate of decline. The monitoring schemes will have higher power to detect more severe declines.

Program Progress 1996-1998. By 1998, the NBMP had approximately 400 volunteers active annually in bat surveys and a total membership of 1250 people. New members recruited in 1998 alone totaled 540 and recruitment rates have shown no sign of fatigue. Publicity in early 1999 resulted in more than 144 new enquiries from volunteers wishing to take part in NBMP surveys. From 1996-1998, we have run 36 workshops and given 38 talks to local groups. During early 1999, more than 214 people attended training workshops to improve their bat identification skills. The network of maternity colony roost sites of pipistrelle bats being counted has risen from 204 sites in 1997 to 316 sites in 1998 with a total of 412 individual sites. Over 545 volunteers have been issued with forms for 1999. Due to the restricted distribution and low number of known sites, numbers of serotine roosts counted are low; 15 in a pilot study in 1996, 33 in 1997 and 31 in 1998, with a total of 44 individual sites. Similarly low numbers of sites have been counted for lesser horseshoe bats; 85 sites in 1996 and 54 sites in 1997, with data currently being compiled for 1998. We need to increase the number of sites within these two schemes. The network of hibernation sites with data being collected was 155 sites in 1997 and 163 sites in 1998. In field surveys during 1998, 182 sites were surveyed for noctule, serotine and *P. pipistrellus* and *P. pygmaeus* bats (NSP survey) and 237 sites were surveyed for Daubenton's bats. This year 295 volunteers have been issued with NSP sites and 398 people issued with Daubenton's sites to survey. Data return rates for schemes vary from 30 B 60 %. A preliminary analysis of data collected over three years (1993-1995) for the lesser horseshoe bat used Poisson regression analysis of peak counts at sites and found no significant trend. Counts were found to be overdispersed with a dispersion parameter of around 4.4.

To date no results have been formally published and the final results and an analysis of the monitoring data will not be available until after all the field work has been completed in 2000. Preliminary analyses reported in internal reports have been received well by the DETR. The monitoring techniques being developed have already provided the model for developing standard transboundary monitoring techniques for bats in Europe, which was accepted by Parties of the European Bats Agreement in 1998. The success in recruiting and co-ordinating a volunteer work force has prompted the DETR to undertake a scoping study to assess how volunteers might be involved in a national mammal monitoring program. We are confident that the project will yield valuable information that will help the development of a conservation strategy for bats in the UK.

References

Bunce, R. G. H., C. J. Barr, R. T. Clarke, D. C. Howard, and A. M. J. Lane. 1996. Land classification for strategic ecological survey. Journal of Environmental Management 47:37-60.

Cochran, W.G. 1977. Sampling techniques. 3rd ed. Wiley and Sons, NY. 428 pp.

Harris, S., P. Morris, S. Wray, and D. Yalden. 1995. A review of British mammals: population estimates and conservation status of British mammals other than cetaceans. Joint Nature Conservation Committee, Peterborough.

Hooper, J. H. D. 1983. The study of horseshoe bats in Devon caves: a review of progress 1947-1982. Studies in Speleology 4:59-70.

James, F. C,. C. E. McCulloch, and D. A. Wiedenfield. 1996. New approaches to the analysis of population trends in land birds. Ecology 77:13-27.

Ransome, R. D. 1989. Population changes of Greater horseshoe bats studied near Bristol over the past twenty-six years. Biological Journal of the Linnean Society 38:71-82.

Robinson, D. L. 1987. Estimation and use of variance components. The Statistician 36:3-14.

Stebbings, R. E. 1988. Conservation of European bats. Christopher Helm Publishers, London. 246 pp.

Stebbings, R. E. and H. R. Arnold. 1987. Assessment of trends in size and structure of a colony of the Greater horseshoe bat. Symposium of the Zoological Society of London 58:7-24.

Walsh, A. L. and S. Harris. 1996a. Foraging habitat preferences of vespertilionid bats in Britain. Journal of Applied Ecology 33:519-529.

Walsh, A. L. and S. Harris. 1996b. Factors determining the abundance of vespertilionid bats in Britain: geographic, land class and habitat relationships. Journal of Applied Ecology 33:508-518.

Walsh, A. L., A. M. Hutson, and S. Harris. 1993. UK volunteer bat groups and the British bats and habitats survey. Pages 113-123 *in* K. Kapteyn, editor. Proceedings of the First European bat detector workshop. Netherlands Bat Research Foundation, Amsterdam.

[1] The Convention on the Conservation of European Wildlife and Natural Habitats
[2] European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora
[3] Convention on the Conservation of Migratory Species

Existing Data on U.S. Bat Populations

LAURA E. ELLISON[1], THOMAS J. O'SHEA[1], MICHAEL A. BOGAN[2], A. LANCE EVERETTE[1], and DIANE M. SCHNEIDER[1]

[1]U.S. Geological Survey, Midcontinent Ecological Science Center, 4512 McMurry Ave., Fort Collins, CO 80525-3400

[2]U.S. Geological Survey, Midcontinent Ecological Science Center, Museum of Southwestern Biology, University of New Mexico, Albuquerque, NM 87131

Introduction. There are about 45 species of bats in the United States with additional species in the Pacific and Caribbean trust territories. Colonies of some of these bat species have declined or disappeared in recent decades, and conservationists and researchers have drawn attention to a need to develop bat inventory and monitoring programs nationwide. Several bats are listed by the U.S. Fish and Wildlife Service as endangered or threatened, and many are considered "species of concern". Despite this increasing attention and concern for bat populations, efforts for determining bat status and trends have been fragmented among agencies and organizations. In late 1995 the U.S. Geological Survey, then National Biological Service, began a project to compile existing population information for bats in the United States and Territories. We designed a relational database in Microsoft Access with 14 linked tables of information. This database will hereafter be called the U.S. Geological Survey Bat Population Database, or BPD. One record in the BPD consists of an observation on a particular date at a particular location linked to a bibliographic citation (publication, unpublished report, theses/dissertation) or contributor (e.g., Natural Heritage program, game & fish department, U.S. Forest Service), and species. Sensitive location information (e.g., UTMs, latitudinal and longitudinal data, etc.) is located in a separate database. There are 4 different types of observations (colony, mist-net, trap, and acoustic), and multiple types of observations can be linked to a single record. With this database design, information can be easily extracted and sorted by species, location, state, county, colony type (i.e., hibernacula, maternity, bachelor) or structure (i.e., cave, mine, tree, building), estimation methods, types of observations (colony, mist-net, trap, acoustic), data source, land management authority, and other attributes. Assembly of such a database was a first step in assessing existing information to test hypotheses on bat population trends on a national scale. It also provides historical information for those planning future comparisons of past and present colony sizes, and may be useful for macrobiogeographical analyses of bat colony size and other ecological patterns.

Methods. Our emphasis for initial data acquisition and entry was on colonial species. Mist-netting, trapping, and acoustic records are therefore minimally represented in the BPD. Because of this early emphasis, summary analyses reported in this abstract are from colonial observations only. We began our acquisition of existing data by performing an extensive literature search. We have reviewed over 1,500 references from peer-reviewed journals, books, agency reports, and theses/dissertations. Each publication was reviewed several times for mention of a roost location, colony size, and presence of a particular species. Not all publications necessarily include bat population monitoring over time, and many are one-time observations. There are currently 925 bibliographic references in the database and 430 of these have associated population observations. In addition to a literature search, we have contacted 48 Natural Heritage Programs and have received information from 20 of these programs, 8 of which gave us immediate access to bat population information (Alabama, Florida, Indiana, Maine, Montana, North Carolina, North Dakota, and Oregon). States and individual researchers conducting long-term bat monitoring programs have also been contacted within the last 4 years.

Results. As of August 1999, the BPD contained nearly 18,000 observations for 40 species and 3 subspecies. Eighty-three percent of these records are observations at colonies. Fifteen percent of the observations are from mist-netting records and the remaining 2% are from trapping, acoustic, and miscellaneous data types. There are 22 different categories of data sources for colony observations. Almost half of the observations are from the literature (29% publications, 13% theses/dissertations, and 6% unpublished reports). Nearly a quarter of the observations are from the Pennsylvania Game Commission Winter Bat Hibernacula Survey (24.8%). The remainder of the observations are from Natural Heritage databases (7%), U.S. Forest Service databases (3%), Colorado Division of Wildlife (2%), other state fish & game departments (8%), and individual researchers (7%). Of 4,770 colony locations with an associated management authority given, 40% are located on private property, 32% are owned by the state, 27% are federally owned (U.S. Forest Service, National Park Service, Bureau of Land Management), and 1% are owned municipally.

Below we summarize information in the Bat Population Database by species groupings. For each of the following tables (Tables 1-6), we include the number of observations by species, the number of colony locations with time series of more than 3 years, the number of colony locations with time series of at least 10 years, and the number of surveys conducted post-1990. The time series categories (≥3 years and ≥10 years) do not necessarily consist of surveys made in consecutive years, but may also include surveys spanning several decades.

Phyllostomidae:

For the New World family Phyllostomidae, we have records for the following species *Macrotus californicus*, *Choeronycteris mexicana*, *Leptonycteris curasoae*, *L. nivalis*, and *Monophyllus redmani* (Table 1). The data in the BPD are mostly historical for this group of bats.

Table 1. Summary of colony data compiled in the Bat Population Database for the Phyllostomids.

Species	Observations in BPD (# of locations)	# of colonies with ≥3 years of surveys	# of colonies with ≥10 years of surveys	# of post-1990 surveys (%)
Macrotus californicus	69(14)	2	0	0 (0%)
Choeronycteris mexicana	19(10)	0	0	0 (0%)
Leptonycteris curasoae	77(23)	6	0	0 (0%)

L. nivalis	54(9)	2	0	0 (0%)
Monophyllus redmani	1	0	0	0 (0%)

Of the information we have gathered so far, only 3 of these species have locations with more than 3 years of surveys, and no species has a time series exceeding 10 years. The most complete time series we found for *M. californicus* was at the Fortuna Mine in California. From 2 February 1958 through 12 November 1960, 34 surveys were conducted during all seasons of the year. For both *L. curasoae* and *L. nivalis*, the best series of repeat visits is for Colossal Cave in Arizona. From 8 May 1954 to June 1985, 19 visits were made. All records in the BPD for phyllostomids are from publications and theses/dissertation sources and most records are for Arizona.

Vespertilionidae:

Myotis: We have records for the following *Myotis spp*: *Myotis ciliolabrum*, *M. grisescens*, *M. septentrionalis*, *M. sodalis*, *M. thysanodes*, *M. volans*, *M. leibii*, *M. californicus*, *M. evotis*, *M. keenii*, *M. lucifugus*, *M. velifer*, *M. yumanensis*, *M. austroriparius* (Table 2). We have no information in the database for *Myotis auriculus*. We have the greatest number of observations for *M. sodalis* and this species also has the most colonies with more than 3 years of surveys and more than 10 years of surveys. The majority of the observations for this species are surveys conducted at hibernacula (93%) and almost half (46%) are from hibernacula in Kentucky. If a species is endangered, there are more data available on its population status. For most of these species, a large proportion of the records are from the past decade.

Table 2. Summary of colony data compiled in the Bat Population Database for *Myotis spp*.:

Species	Observations in BPD (# of colonies)	# of colonies with ≥3 years of surveys	# of colonies with ≥10 years of surveys	# of post-1990 surveys (%)
Myotis ciliolabrum	324 (141)	10	0	266 (82%)
M. grisescens	924 (214)	76	9	146 (16%)
M. septentrionalis	885 (551)	32	5	389 (44%)
M. sodalis	2032 (647)	96	18	534 (26%)
M. thysanodes	134 (73)	3	0	72 (54%)
M. volans	240 (133)	8	0	155 (65%)
M. leibii	752 (491)	28	5	340 (45%)
M. californicus	41 (36)	0	0	10 (24%)
M. evotis	116 (84)	2	0	77 (66%)
M. keenii	18 (12)	2	0	0 (0%)
M. lucifugus	1465 (786)	69	5	605 (41%)
M. velifer	310 (75)	17	0	50 (16%)

M. yumanensis	124 (58)	6	0	29 (23%)
M. austroriparius	290 (80)	18	1	71 (25%)

Lasiurus: We have records for the following species: *Lasiurus cinereus*, *L. ega*, *L. intermedius*, *L. cinereus semotus*, *L. seminolus*, *L. xanthinus*, *L. borealis*. We have no information entered for *Lasiurus blossevilli* (Table 3). We have no time series for this group of bats and most of the information is historical (pre-1990). The majority of observations for the *Lasiurus spp.* are for *L. borealis* with 66 total records and 27 roost sites (mostly tree roosts). This illustrates the lack of information in the literature on monitoring foliage-roosting species.

Table 3. Summary of colony data compiled in the Bat Population Database for the *Lasiurus spp.*:

Species	Observations in BPD	# of roosts	# of post-1990 surveys (%)
Lasiurus cinereus	37	13	1 (3%)
L. ega	3	3	0 (0%)
L. intermedius	6	5	0 (0%)
L. cinereus semotus	2	2	0 (0%)
L. seminolus	1	1	0 (0%)
L. xanthinus	2	2	0 (0%)
L. borealis	66	27	3 (4%)

Big-eared bats: Of the "big-eared bats", we have records for the following species: *Euderma maculatum, Corynorhinus townsendii, C. t. ingens, C. t. virginianus, C. rafinesquii,* and *Idionycteris phyllotis* (Table 4). We have the most information on *C. townsendii,* with 991 records at 371 colony locations. This species also has the largest number of colonies with more than 3 years of surveys. Half of the surveys in the database for *C. townsendii* were conducted after 1990, illustrating the increase in conservation interest for this species, and more than half of the surveys for *C. t. virginianus* (63%) were conducted post-1990 reflecting increased concern about the population status for this subspecies.

Table 4. Summary of colony data compiled in the Bat Population Database for the "big-eared bats":

Species	Observations in BPD (# of colonies)	# of colonies with $\geq$3 years of surveys	# of colonies with $\geq$10 years of surveys	% post-1990 surveys (%)
Euderma maculatum	8 (8)	0	0	0 (0%)
Corynorhinus townsendii	991 (371)	54	3	498 (50%)
C. t. ingens	330 (54)	27	7	125 (38%)

C. t. virginianus	54 (12)	6	0	34 (63%)
C. rafinesquii	116 (71)	4	0	26 (22%)
Idionycteris phyllotis	11 (6)	0	0	0 (0%)

Other vespertilionids: For the remainder of the Vespertilionids, we have records for *Lasionycteris noctivagans*, *Pipistrellus hesperus, P. subflavus, Eptesicus fuscus, Nycticeius humeralis,* and *Antrozous pallidus* (Table 5). For these species, most information was historical (pre-1990) although for *E. fuscus*, almost 40% of the observations were made after 1990. We also found the most information on *E. fuscus* (in this group of bats) with 1709 records at 805 locations across more states than any other species (39 states) and also the most variety in roosting structures (15 different structures including buildings, caves, mines, trees, storm sewers, dams, bridges, tunnels to name a few). This illustrates the wide geographic range and generalized roosting habits of *E. fuscus*.

Table 5. Summary of colony data compiled in the Bat Population Database for other Vespertilionids:

Species	Observations in BPD (# of colonies)	# of colonies with $\geq$3 years of surveys	# of colonies with $\geq$10 years of surveys	% post-1990 surveys (%)
Lasionycteris noctivagans	23 (21)	0	0	7 (30%)
Pipistrellus hesperus	23 (19)	0	0	6 (26%)
P. subflavus	1563 (670)	53	7	418 (27%)
Eptesicus fuscus	1709 (805)	46	5	659 (39%)
Nycticeius humeralis	138 (49)	1	0	13 (9%)
Antrozous pallidus	133 (49)	2	0	15 (11%)

Molossidae:

For the family Molossidae, we have information on the following species: *Tadarida brasiliensis, Nyctinomops femorosaccus, N. macrotis, Eumops glaucinus,* and *E. perotis* (Table 6). We have no information in the database for *Eumops underwoodi*. The most complete information exists for *T. brasiliensis* with 499 records at 107 locations. Eagle Creek Cave, Greenlee Co., Arizona is the only location currently in the BPD with a time series exceeding 10 years in which estimates were made. There are 11 population estimates for Eagle Creek Cave spanning from 30 July 1948 through 16 July 1970. We have many other locations (106) in the BPD for *T. brasiliensis*, but only Eagle Creek Cave has an excess of 10 years of population surveys.

Table 6. Summary of colony data compiled in the Bat Population Database for the Molossids:

Species	Observations in BPD (# of colonies)	# of colonies with $\geq$3 years of surveys	# of colonies with $\geq$10 years of surveys	% post-1990 surveys (%)
Tadarida brasiliensis	499 (107)	12	1	83 (17%)
Nyctinomops femorosaccus	5 (5)	0	0	0 (0%)
N. macrotis	10 (8)	0	0	0 (0%)
Eumops glaucinus	3 (3)	0	0	0 (0%)
E. perotis	30 (13)	0	0	0 (0%)

Discussion. Several issues were revealed while compiling and summarizing the Bat Population Database. The methods for estimating population size and the quality of the estimates reported for the species summarized above vary dramatically. Out of almost 15,000 colony estimates, only 12 estimates have an associated standard error (0.08%). Less than a quarter of the estimates include a lower and an upper limit, or range, for their population count. Methodologies used to estimate population size vary depending upon the colony type: most summer colonies are "emergence" estimates whereas most hibernacula surveys are "counts" within a roost, but many variations of these generalized methods are reported in the literature. Additionally, methods reported are usually not described in any great detail, illustrating the lack of a standardized protocol for measuring bat population status. The BPD is not complete: it is a work in progress. We are constantly updating records when new information becomes available, and we still welcome additional data sources. There are close to 700 literature citations that still need to be reviewed for mention of bat population counts.

Despite the above limitations to the database, its potential uses are numerous. It may provide a basic framework for planning future monitoring efforts, it may be useful in looking at macrobiogeographical patterns or examining how habitat and geographic features relate to colony sizes of bats, and it can provide a reference for finding historical information on bat surveys by site, state, and species. Many of the surveys summarized above, especially for the "big-eared bats" and the *Myotis spp.*, were conducted after 1990. This reflects the recent concern among conservationists to develop and maintain long-term monitoring programs for bats. Results from statistical trends for selected colony locations and species will be reported and discussed along with additional uses the BPD offers bat researchers and monitoring programs during the workshop in Estes Park, Colorado, in September 1999.

A Critical Look at National Monitoring Programs for Birds and Other Wildlife Species

JOHN R. SAUER[1]

[1]U.S. Geological Survey, Patuxent Wildlife Research Center, 11510 American Holly Drive, Laurel, MD 20708

Abstract: Concerns about declines in a variety of taxa have created a great deal of interest in survey development. Because birds have traditionally been monitored by a variety of methods, bird surveys form natural models for development of surveys for other taxa. Here, I suggest that most bird surveys are not appropriate models for survey design. Most lack important design components associated with estimation of population parameters at sample sites or with sampling over space, leading to estimates that may be biased. I discuss the limitations of national bird monitoring programs designed to monitor population size. Although these surveys are often analyzed, careful consideration must be given to factors that may bias estimates but cannot be evaluated within the survey. The bird surveys with appropriate designs are generally components of management programs that have specific information needs. The experience gained from bird surveys provides important information for other taxa, and statistical developments in estimation of population sizes from counts provide new approaches to overcoming the limitations evident in many bird surveys. Design of surveys is a collaborative effort, requiring input from biologists, statisticians, and from the managers who will use the information from the surveys.

Introduction. Birds are a highly visible and charismatic component of the natural world, and are both well known to the public and often viewed as indexes to quality of nature. Most bird species are protected by international treaties that create a legal mandate to monitor their populations, and hunted species are particularly well monitored by Federal agencies. Also, volunteers have proven to be enthusiastic counters of birds in large-scale projects such as the North American Breeding Bird Survey (BBS) and the Christmas Bird Count (CBC). Consequently, enormous amounts of information are available on counts of birds in North America, and a remarkable number of projects exist that purport to function to provide population information on birds to assist in conservation activities. These activities include breeding and wintering bird atlases, roost counts, constant-effort mist netting, acoustic sampling, radar imaging of migrating birds, roadside survey counts, nest box monitoring, aerial surveys, point counts, play-back counts, and many other methods of encountering birds (e.g., Sauer and Droege 1990).

Even though all of these programs provide information about bird populations, there is still a great deal of controversy regarding whether these surveys provide useful results for population management. Much of this controversy is based on statistical concerns that the design of the surveys do not permit unbiased estimation, and in part reflects recent advances in understanding of monitoring methods. Our knowledge of what constitutes a reasonable survey is much more sophisticated now than it was several decades ago, we have a much clearer view of what management needs are for birds and how surveys should be designed to provide information to assist in achieving management goals, and technical tools for analysis and integration of data have undergone remarkable changes over the past few years. However, many new programs for surveying birds duplicate all the deficiencies of earlier programs because they either are not sensitive to the management need that motivates them or they fail to appropriately sample the population of interest. Reasonable surveys, when they exist, represent a collaboration between management, biological, and statistical expertise. Unfortunately, the interdisciplinary nature of survey design and implementation is often ignored in survey development, leading to surveys that are limited with regard to at least one critical component. In this paper, I review some notions of what constitutes a reasonable survey, and discuss a selection of bird surveys in the context of these notions.

Why Monitor? Many bird surveys are developed with only vague notions about the uses of the survey results. For example, surveys on Federal lands sometimes result from legislative mandates to monitor, some surveys are established to provide birding activities for the public, and other programs develop simply from the perception that useful information can be gathered from a new technological tool such as weather radar or sound recording equipment. Vagueness associated with goals and uses of survey information often makes it impossible to design a relevant survey. Unless goals are precisely defined, it is impossible to define a population to be sampled, develop a survey design to meet the goals, or to judge the relative merits of alternative procedures.

Most relevant surveys are tied directly to management needs. Migratory bird managers use estimates of change in population size from waterfowl surveys to evaluate the consequences of harvest regulations; land managers use estimates of population change to judge the effectiveness of land management activities. Traditional management of migratory birds has relied primarily on time series of estimates of population size of birds to assess population status. Although this information has obvious relevance, it is often maddeningly difficult to understand the causes of population change from these data, and several bird surveys focus on estimation of primary demographic parameters such as survival or productivity (e.g., DeSante 1992) in an attempt to estimate parameters that are more likely to be associated with causal factors. Still, many biologists view estimation of population size (or change in population size) as a primary goal of surveys, and I will primarily discuss surveys that address this goal.

Design Issues for Wildlife Surveys. An enormous literature exists on designing surveys. In particular, Thompson et al (1998) and Skalski and Robson (1992) provide general reviews of many components of design of wildlife surveys. Surveys are generally based on probability sampling, in which the population is divided up into a series of sample units, each of which has a known probability of appearing in a sample. The actual samples chosen in the survey are selected randomly based on associated probabilities of selection, allowing development of sampling theory and estimates of population attributes. In almost all wildlife surveys, an additional complication exists in that we generally cannot census sample units, and we have to estimate total numbers of animals (our attribute of interest) in each sample unit. Skalski (1994) refers to this as 2-stage sampling, where probability sampling over spatial sampling units is the first stage, and the estimation of animal density within sample units is the second stage. This is an extremely useful distinction, as both components are critical in wildlife survey design. Note that the second stage requires estimation of population size for a known area.

Cochran (1977) outlines components that should be considered when planning and implementing a sample survey:

Development of objectives is needed to provide structure for the project.
The target population must be defined to ensure that it is coincident with the sampled population.
Data to be collected must be relevant to the objectives.
Needed degree of precision must be specified.
Methods of measurement must be chosen.
A sampling frame (listing of all possible sample units) must be developed that covers entire population.
Methods of selecting sample from frame must be defined.
Small-scale trials of design (Pretests, pilot studies) are useful to evaluate efficiency.
Organization of fieldwork must incorporate planning for quality control and quality assurance.
Summary and analysis of data should be considered during survey design.
All surveys must be viewed as providing information to be used in designing future surveys.

Skalski's first stage relates to definition of the target population and development and sampling from the frame, the second stage relates to methods of measurement and collection of relevant data. The other components influence both stages.

Common Problems With Bird Surveys. In my view, most bird monitoring programs are missing several of these components. Often, they lack clear statements of objectives, and have vaguely defined target populations, incomplete sampling frames, and poorly thought out methods of measurement. In most cases, they simply provide incomplete lists of species and numbers of individuals present at a particular time and place. The Christmas Bird Count, which was started to provide a recreational activity for birdwatchers (Butcher 1990), is often considered "the largest wildlife survey in the world (Butcher 1990)." Unfortunately, it is deficient in 2 critical components:

1. The 15-mi diameter "circles" that form the sample units of the counts are not censused. Instead, varying numbers of groups of counters record birds from areas within the circle. Clearly, numbers of birds counted varies with the amount of effort in counting and the competence of the observers, and no attempt is made to estimate the number of birds actually present.

2. The sample units are not randomly selected. Instead, they are generally centered in places likely to be of interest to birders.

The consequences of these deficiencies are obvious. For (1), it is clear that counts from the CBC always underestimate the population size, hence any use of the data requires that we assume that either (a) the counts accurately index the population (i.e., the counts are a constant proportion of the population size) or (b) the variation in the proportion counted can be controlled by use of effort covariates. Unless obviously incorrect assumptions are made, CBC count data cannot be considered a census! For deficiency (2), it is clear that any information from the sample units cannot be used to extrapolate to areas not sampled unless we assume either that (a) they constitute a random sample from the population, or (b) that the lack of representativeness can be controlled for by use of covariates that reflect differences among the actual sample sites and the rest of the area.

Statisticians refer to deficiency (1) as visibility bias in estimation, and deficiency (2) as an incomplete sample frame, and often surveys containing these deficiencies are called "index" surveys in that they explicitly only count parts of the actual population of interest. Note that in the context of surveys, an index is often implicitly defined as a count that is related in some unknown (but assumed to be consistent) way to an underlying parameter. The more common usage refers to the second stage of sampling, as a count collected at a sample unit is often considered to index population size at a site, but it is also useful to consider indexes in the spatial sampling context.

Almost all bird surveys have these deficiencies. Every survey discussed in Sauer and Droege (1990) as providing information on population trends could be categorized as an index survey, and popular bird survey methods such as point counts (Ralph et al. 1995) only index population size at sample sites. For example, the BBS counts are also not censuses, and the BBS sample is confined to roadsides. The only example of a long-term, geographically-extensive survey designed with explicit consideration of both stages of sampling is the Spring Breeding Ground Survey for waterfowl (Smith 1995).

Analysis of Survey Data. Analysis of index surveys has proven to be very controversial. The statistical literature contains many cautions about the limitations of index surveys, for example: "Using just the count of birds detected (per unit effort) as an index (to) abundance is neither scientifically sound nor reliable" (Burnham 1981, p. 325), and "It is imperative in designing the preliminary survey to build in the capability of the sampling program the ability of testing homogeneity of the proportionality factor values..." (Skalski and Robson 1992). Naive analysts of index surveys treat them as single stage sample surveys. That is, they assume that within-site indexes are censuses, treating them as area-specific abundances, then ignore possible sample frame problems and calculate estimates using standard sample survey theory. For example, estimating a total population size of a species from CBS data or using mean counts from BBS routes are examples of the naive approach to survey analysis. Although most analysts recognize that naive analyses of index surveys are likely to lead to biased estimates (e.g., James et al. 1990; Lancia et al. 1994), many examples exist of inappropriate analyses of index surveys. Generally, appropriate analysis of index surveys tend to be much more complicated (and problematic) than analysis of 2-stage surveys.

<u>Analysis of 2-stage surveys</u>. The 2-stage nature of wildlife surveys always introduces some complications into analysis, in that within-sample unit abundances must be estimated. Two-stage surveys require some statistical modeling to estimate densities in the second stage, but then are design-based, in that the probabilistic design of the sampling in the first stage is model-free.

This means that some statistical procedure such as capture-recapture is used to estimate visibility rates of animals within sample units, but once they are estimated the first stage can be treated using standard sample survey theory.

Analysis of index surveys. Index surveys often cannot be assumed to provide censuses with sites or even fixed areas of sampling. Appropriate analysis of data from surveys such as the CBC requires that deficiencies of the surveys be acknowledged and accommodated. Generally, these accommodations involve additional statistical modeling that seeks to minimize bias in estimation at each stage of the survey. For the second stage, that involves identifying factors that might influence the visibility rates of birds (such as effort in the CBC), and modeling the effects of effort on counts as part of the analysis. For the first stage, factors such as habitat areas within regions form possible covariates. For either stage, resulting estimates are model-based, in that it must be assumed that the covariate adjustments adequately accommodate the deficiencies of the original sample. Care must be taken, however, to distinguish covariates influencing the proportion counted from covariates related to actual population sizes; the former should be included in analyses and the latter should not; covariates influencing both introduce confounding (e.g., Bennetts et al. 1999).

Often, index surveys are used to estimate change over time in population size, rather than actual population size. Because it is acknowledged that sample units are vaguely defined in index surveys, covariate adjustments that attempt to control for visibility differences over time within sites often have more credibility than adjustments that control for visibility differences among sites. This approach is used to estimate population change in the BBS, in which observer differences are controlled using covariates in a loglinear model (e.g., Link and Sauer 1998). Model-based approaches to analysis of index surveys still have assumptions, and the validity of the overall results depends on how well our model accommodates differences in visibility. Of course, many factors that influence visibility are not observed and cannot be modeled (Lancia et al. 1994). Nevertheless, this model-based approach to survey analysis provides the only means to enhance the credibility of most bird surveys.

What Can be Done to Develop Monitoring Programs for Species that are Difficult to Survey? Because of widespread interest in monitoring, a variety of groups have been attempting to develop surveys for taxa that have never been effectively monitored. For example, regional surveys are under development for marsh-breeding birds, amphibians, and invertebrate species. Unfortunately, many of these projects are at risk of duplicating the mistakes of earlier programs. In particular, the BBS is often presented as a model for these developing programs, and readily-available results from the BBS (e.g., Sauer et al. 1997) tend to reinforce the notion that the large amounts of information available from the survey overwhelm the potential deficiencies of the survey. In my view the BBS can provide reasonable results in many cases, but the untestable assumptions implicit in analysis must always be considered when interpreting results from the survey (Link and Sauer 1998) and corroborative evidence is often critical as confirmation of results when BBS data are used in management. Incorporating tests for visibility differences and correcting sampling frame deficiencies in the BBS would greatly enhance the credibility of the results.

The Skalski (1994) formulation of biological sampling as a 2-stage process provides a reasonable and productive starting point for development (and improvement) of any monitoring program. All surveys must be judged in terms of their ability to adequately sample within sites and over space. For many taxa presently considered for survey development, indexes to abundance exist but little work has been conducted on development of efficient methods for estimation of visibility rates in the context of these indexes. Development of these methods, and incorporation of visibility rate estimation into routine sampling, are critical components of any monitoring program.

Fortunately, many tools now exist for survey development that can be very effectively applied in new programs. Recent years have seen an enormous amount of development of statistical theory and methods for visibility rate estimation, and Geographic Information Systems provide a unique opportunity to develop and test alternative sampling frames. The challenge is for biologists to remain sensitive to the need for statistical rigor in survey design, and for statisticians to remain sensitive to biological concerns.

A Final Comment. One important limitation of operational survey programs is the inertia associated with historical data. Many managers are reluctant to modify surveys because of concerns of continuity of information and fears of undermining the credibility of the program. However, all surveys need to be viewed as imperfect products subject to constant revision as our understanding of populations and methods changes. In this context, it is productive to evaluate existing surveys, determine where model-based assumptions must be applied for analysis, and devote effort to development of modified sampling methods that will allow for direct estimation of population parameters.

References

Bennetts, R. E., W. A. Link, J. R. Sauer, and P. W. Sikes, Jr. 1999. Factors influencing counts in an annual survey of snail kites in Florida. Auk 116:316-323.

Burnham, K.P. 1981. Summarizing remarks: environmental influences. Pages. 324-325 *in* C. J. Ralph and J. M. Scott, editors. Estimating numbers of terrestrial birds. Studies in Avian Biology No.6, Cooper Ornithological Society, Lawrence, KS.

Butcher, G. S. 1990. Audubon Christmas Bird Counts. Pages 5-13 in J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service, Biological Report 90.

Cochran, W. G. 1977. Sampling techniques. 3rd ed. Wiley and Sons, NY. 428 pp.

DeSante, D. F. 1992. Monitoring avian productivity and survivorship (MAPS): a sharp, rather than blunt, tool for monitoring and assessing landbird populations. Pages 511-521 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: populations. Elsevier, NY.

James, F. C., C. E. McCulloch, and L. E. Wolfe. 1990. Methodological issues in the estimation of trends in bird populations with an example: the Pine Warbler. Pages 84-97 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish Wildlife Service, Biological Report 90.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, MD.

Link, W. A., and J. R. Sauer. 1998. Estimating population change from count data: application to the North American Breeding Bird Survey. Ecological Applications 8:258-268.

Ralph, C. J., J. R. Sauer, and S. Droege, editors. 1995. Monitoring bird populations by point counts, USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.

Robbins, C. S., D. Bystrak, and P. H. Geissler. 1986. The breeding bird survey: its first fifteen years, 1965-1979. U.S. Fish Wildlife Service, Resource Publication 157.

Sauer, J. R., and S. Droege, editors. 1990. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish. Wildlife Service, Biological Report 90.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, and B. G. Peterjohn. 1997. The North American breeding bird survey results and analysis. Version 96.4. Patuxent Wildlife Research Center, Laurel, MD http://www.mbr-pwrc.usgs.gov/bbs/bbs.html

Skalski, J. R. 1994. Estimating wildlife populations based on incomplete areas surveys. Wildlife Society Bulletin 22:192-203.

Skalski, J. R., and D. S. Robson. 1992. Techniques for wildlife investigation: design and analysis of capture data. Academic Press, Inc., NY. 237 pp.

Smith, G. W. 1995. A critical review of the aerial and ground surveys of breeding waterfowl in North America. U.S. Department of the Interior, National Biological Service, Biological Science Report 5.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring Vertebrate Populations. Academic Press, NY. 365 pp.

Warm Season Colonies of Free-Tailed Bats (*Tadarida brasiliensis*)

GARY F. McCRACKEN[1]

[1]Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996-0810

The Brazilian free-tailed bat (*Tadarida brasiliensis*) is one of the most abundant, conspicuous, and widely distributed bat species in North America. They also show substantial diversity in behavior. *T. b. mexicana* (the Mexican free-tailed bat) is typically migratory, spending winter months in central and southern Mexico where they roost primarily in caves and man-made structures in colonies of a few hundred to many thousands. Northward migration of up to 1,300 km occurs between February and April, and the largest colonies are found in caves in northern Mexico and the southwestern United States between May and October. These colonies consist mostly of reproductive females and their offspring. Other populations of *T. b. mexicana* in California and southern Oregon, and those of *T. b. cynocephala* in the southeastern United States, are year-round, non-migratory residents of those regions. Brazilian free-tailed bats in these populations hibernate during cold weather and roost in much smaller colonies, mostly in man-made structures. Little has been reported regarding the behavior or natural history of the other subspecies, and most information concerns migratory populations of *T. b. mexicana* (Wilkins 1989; McCracken and Gustin 1991).

In the 1950's and early 1960's, mid-summer colonies of adult free-tailed bats in 20 caves in Texas, Oklahoma, New Mexico, and eastern Arizona were estimated to total about 150 million individuals (Davis et al. 1962; Constantine 1967; Cockrum 1969; Glass 1982). Allison's (1937) exit count of 8.7 million bats emerging from Carlsbad Caverns, New Mexico on June 16, 1936, is the earliest published estimate of a colony's size, and is the source of the now accepted size of the historic bat population of Carlsbad. Allison (1937) calculated this number from the duration of the bats' emergence, and visual estimates of their flight speed, the cross-section of the emerging column, and the density of bats in the column. Allison (1937) also reported the suggestion of Vernon Bailey (Animal Life in Carlsbad Caverns, 1928) that still photography and motion pictures could be used to effectively estimate the number of emerging bats. In 1957, Constantine (1967) measured the amount of cave surface occupied by the bats in Carlsbad, multiplied this by average roosting densities, and estimated that between 1 to 4 million bats inhabited the Caverns. Mark/recapture studies done at the same time by Constantine gave similar estimates. In the first effort to use still photography, Humphrey (1971) estimated that the numbers of bats emerging from Vickery Cave, Oklahoma in the summer of 1969 ranged from less than 100,000 bats in early May to a peak of approximately 1 million in late August and September. Subsequently, on September 1, 1973, Altenbach et al. (1979) combined high speed motion pictures and still photography to estimate the colony size at Carlsbad Caverns at 218,000 bats, or about 5% of Allison's (1937) estimate. In more recent years, photographic estimates of the Carlsbad population have fluctuated between about 250,000 and 1 million bats (Geluso et al. 1987).

While the population decline at Carlsbad Caverns is the best known, Cagle (1950) appears to be the first author to note the apparent decline of a large colony of Mexican free-tailed bats. Ney Cave in Texas has been mined for guano since the Civil War. Cagle (1950) reported that while, as of 1950, 20 to 30 tons of guano were still taken annually from Ney Cave, the guano miners were concerned because the amount of guano available each year was decreasing, and, it appeared, so were the numbers of bats. The decline of the bat population at Eagle Creek Cave, Arizona, however, is widely cited as the most dramatic. Based on the numbers of bats roosting per unit area at a number of sample sites and the estimated total cave surface area occupied by the bats, Cockrum (1969) estimated a late-June peak population size of between 25-50 million individuals in Eagle Creek Cave. As late as 1963, the bat population at Eagle Creek Cave was said to exceed 25 million, but by June 1969, the population was estimated at only 30,000 bats (Cockrum 1970), resulting in the widely cited conclusion of a nearly 99.9% reduction (Cockrum 1970; McCracken 1986, 1989; Tuttle 1994).

Currently, the largest warm season free-tailed bat populations are in the Edward's Plateau region of Central Texas. Davis et al. (1962) estimated that, in 1957, the mid-summer populations of free-tailed bats in 13 large caves in Central Texas contained a combined total of over 100 million individuals. Seven of these caves each were cited as having up to 10 million bats, with the largest, Bracken Cave, having an estimated 20 million bats. Davis et al. (1962, p. 319) provided little detail in describing their estimation procedures, stating that "...Recorded figures are based on a combination of estimates - density inside cave, capture rates in the trap, and density and duration of exodus flights". They also were circumspect with regard to their numbers "....The precision of our estimates of abundance of guano bats is low as attested by the experiences of ourselves and others in trying to measure the number of bats present in a guano bat cave. Population figures we report are useful at most for comparing relative orders of magnitude."

Davis et al.'s (1962) estimates from 1957 - 20 million bats in Bracken Cave, 4 to 6 million in Eckert James River Cave, 8 to 10 million in Frio Cave, 10 million in Ney Cave - are often quoted as current reality over 40 years later (McCracken 1986, 1989; Wahl 1993; McCracken and Gustin 1991; Tuttle 1994), and almost always without the circumspection of Davis et al. (1962). The fact is, our best estimates of the sizes of these largest free-tailed bat colonies date from the 1950's and were made by a variety of workers using various and largely unspecified procedures. These numbers are quoted simply because they are the only numbers we have.

While population size estimates from the 1950's are suspect and may have no bearing on current reality, there is no question that major declines have occurred in Carlsbad, Eagle Creek, and a number of other caves, including many caves in Mexico where populations have been extirpated or largely extirpated (McCracken 1986; Walker 1995). Zero is an easy number to approximate, and error limits on small estimates will be small. Indeed, the estimates of the Carlsbad population from 1957 to the present are probably quite accurate. However, it seems safe to assume that we have no real idea of the numbers of bats in Bracken, Ney, Frio, James River, and most of the other caves.

The Programa para Conservacion Murcielago Migratorios (PCMM), was established in 1994 by Bat Conservation International and concerned American and Mexican biologists as a response to obvious declines and the general lack of information on the status of Mexican free-tailed bat colonies in both the U.S. and Mexico (Walker 1995). Establishing accurate base-line counts of the numbers of Mexican free-tailed bats, and monitoring trends in population sizes, in warm season and winter colonies is a primary goal of this initiative. In 1995, an unsuccessful attempt was made to estimate the sizes of the Bracken and Eckert-James River cave colonies using infrared video techniques that had been successful in counting much smaller grey bat colonies (B. Sabol pers. comm.). Currently, other efforts are in progress. 1) Photo points have been established at fixed locations within several cave roosts to monitor population trends (B. Keeley, pers. comm), and 2) a new generation of high resolution infrared videography is being tested to obtain accurate counts of the numbers of individuals at the Bracken, Eckert James River and Davis Cave Colonies (T. H. Kunz pers. comm). Calibration of cave colony sizes using the new generation of IR videography may ultimately allow estimation and monitoring of colony sizes using the U.S Weather Service's NEXRAD WRS 88 doppler radar facilities.

References

Allison, V.C. 1937. Evening bat flight from Carlsbad Caverns. Journal of Mammalogy 18:80-82.

Altenbach, J. S., K. N. Geluso, and D. E. Wilson. 1979. Population size of *Tadarida brasiliensis* at Carlsbad Caverns in 1973. Pages 341-348 *in* H. H. Genoways and R. J. Baker, editors. Biological investigations in the Guadelupe Mountains National Park, Texas. National Park Service Proceedings and Transactions Series Number 4.

Bailey, V. 1928. Animal life of the Carlsbad Caverns. American Society of Mammalogists Monograph 3. 195 pp.

Cagle, F. R. 1950. A Texas colony of bats, *Tadarida mexicana*. Journal of Mammalogy 31:400-402.

Cockrum, E. L. 1969. Migration in the guano bat *Tadarida brasiliensis*. University of Kansas Museum of Natural History, Miscellaneous Publication 51:303-336.

Cockrum, E. L. 1970. Insecticides and guano bats. Ecology 51:761-762.

Constantine, D. G. 1967. Activity patterns of the Mexican free-tailed bat. University of New Mexico Bulletin Biological Series 7:1-79.

Davis, R. B., C. F. Herreid, II, and H. L. Short. 1962. Mexican free-tailed bats in Texas. Ecological Monographs 32:311-346.

Geluso, K. N., J. S. Altenbach, and R. C. Kerbo. 1987. Bats of Carlsbad Caverns National Park. Carlsbad Caverns Natural History Association, Carlsbad, NM. 33 pp.

Glass, B. P. 1982. Seasonal movements of Mexican free-tailed bats *Tadarida brasiliensis mexicana* banded in the Great Plains. Southwestern Naturalist 27:127-133.

Humphrey, S. R. 1971. Photographic estimation of population size of the Mexican free-tailed bat, *Tadarida brasiliensis*. American Midland Naturalist 86:220-223.

McCracken, G. F. 1986. Why are we losing our Mexican free-tailed bats? Bats. Newsletter of Bat Conservation International 3:1-4. (reprinted. 1987. Endangered Species Technical Bulletin 4:1-4).

McCracken, G. F. 1989. Cave conservation: special problems with bats. The National Speleological Society Bulletin 51:47-51.

McCracken, G. F., and M. F. Gustin. 1991. Nursing behavior in Mexican free-tailed bat maternity colonies. Ethology 89:305-321.

Tuttle, M. D. 1994. The lives of Mexican Free-tailed bats. Bats 12:6-14.

Wahl, R. 1993. Important Mexican free-tailed bat colonies in Texas. Pages 47-50 *in* J. Jorden and R. Obele, editors. 1989 National Cave Management Symposium Proceedings. Texas Parks and Wildlife Press, Austin, TX.

Walker, S. 1995. Mexico-U.S. partnership makes gains for migratory bats. Bats 13:3-5.

Wilkins, K. T. 1989. *Tadarida brasiliensis*. Mammalian Species 331:1-10.

Censusing Pacific Island Flying Foxes: a Review of Count Methods and Recent Population Trends

GARY J. WILES[1], ANNE P. BROOKE[2], RUTH C.B. UTZURRUM[3], DAVID J. WORTHINGTON[4], and WILLIAM E. RAINEY[5]

[1] Division of Aquatic and Wildlife Resources, 192 Dairy Rd., Mangilao, GU 96923

[2] Box 102, Newfield, NH 08356

[3] Department of Marine and Wildlife Resources, Box 3730, Pago Pago, AS 96799

[4] National Park Service, Capitol Reef National Park, HC 70 Box 15, Torrey, UT 84775

[5] 2556 Hilgard Ave., Berkeley, CA 94709

Introduction. We provide a summary of census techniques and population estimates for three species of flying foxes (*Pteropus mariannus, P. tonganus, and P. samoensis*) found in the U.S. Pacific island territories of Guam, the Commonwealth of the Northern Mariana Islands (CNMI), and American Samoa. Reliable census data are necessary for these species because each has experienced population declines in recent decades. Population assessments for these species have been underway for only the last 20-25 years and early efforts often resulted in highly erroneous estimates. Although more recent efforts have attempted to standardize methodologies, the data generated are neither highly accurate nor statistically rigorous.

Census Considerations. Censusing Pacific island flying foxes requires methodologies that differ significantly from those used for North American microchiropteran bats. Surveys must be designed to count both colonial and spatially dispersed solitary components of *Pteropus* populations. Further, variation in the degree of coloniality as well as temporal variation in activity patterns have been observed among subpopulations on different islands in the Marianas, requiring that biologists be familiar with the specific characteristics of each population and island that will be surveyed.

Flying fox movements are closely linked to changing food availability; observers must be aware that census results may be affected by seasonal changes in fruiting and flowering patterns, which also vary annually. Seasonal differences in reproductive activity may also influence results. Logistical challenges are often immense, and transportation and manpower needs can make surveys expensive and difficult to conduct on some islands. Information on species behavior and island traits, which affect censusing efforts, are provided below.

<u>Species Characteristics</u>. All three species are large in size (wingspans of 90-120 cm), making them visible in flight at distances of up to 1 km. *P. mariannus* and *P. tonganus* are primarily nocturnal, but can also be active in the daytime, especially in the early morning and late afternoon. Both species tend to be highly colonial, with smaller portions of populations living

solitarily; however, this can vary greatly among islands. *P. samoensis* is primarily active in the late afternoon and night, but can be seen throughout the day, and is mainly solitary. The colonies of all species occur in treetops or within the canopy, and vary in size from a few individuals to rarely up to 60 animals in *P. samoensis*, 2,000 animals in *P. mariannus*, and 4,000 or more animals in *P. tonganus*. Flying foxes are strong fliers and have the potential to cover an entire island in a single night, as well as move distances of up to 100 km between islands (Wiles and Glass 1990). Populations may be relatively mobile in response to changing food availability and human disturbance. Bats are hunted on all islands, which can force them into using the roughest terrain and possibly becoming more nocturnal.

<u>Island Characteristics</u>. U.S. territory islands with flying foxes range in size from a few hectares to 540 km^2. Severe topography and rugged shorelines can make access to count sites difficult on some islands, especially in the remote northern Marianas, where boat or helicopter travel is necessary. Heat, high rainfall, and the annual typhoon or cyclone season can result in harsh field conditions.

Count Techniques. Several types of census methods have been employed to count these species, with most surveys to date using a combination of the techniques described below.

<u>Direct Counts at Colonies</u>. Flying foxes in aggregations are best counted when their roosting trees can be viewed at relatively close distances (i.e., 100-300 m) from suitable overlooks. Observers should use spotting scopes to enumerate visible animals, which can increase count tallies by up to 20% over binoculars. In locations where bats are sensitive to human presence, viewpoints should be placed downwind of colonies and set back at least 150 m. At densely populated roosts, observers should use visual reference points (e.g., individual trees) to break roosting animals into smaller and more manageable counting units. Even under the ideal viewing conditions, the results of direct colony counts do not represent complete counts, but should be increased by 5-10% to account for animals hidden from sight by foliage or roost mates. Rarely, where flying foxes are tame and the foliage is thin, acceptable counts may be obtained by observers standing beneath roost trees.

<u>Counts of Bats Dispersing from Colonies</u>. These counts are used to estimate the sizes of remote colonies when accurate direct counts are not possible. Observers should position themselves at sites where bats departing colonies are silhouetted against the sky. Counts begin in the early evening and continue until darkness. Because some animals depart unseen or remain in the roost until nightfall, count results represent a subset of the total colony size. Thus, researchers usually multiply their results by some “reasonable” factor to derive an estimated colony size. Nightly differences in emergence patterns of the bats and viewing conditions (e.g., changes in cloud cover) can create considerable variability in count results.

<u>Counts of Non-Colonial Animals</u>. To assess the abundance of solitary flying foxes, researchers have relied on daytime (i.e., late afternoon or early morning) station counts made from vantage points with clear views of the nearby landscape. Observers scan the horizon and intervening terrain with binoculars to count the numbers of bats (usually flying) seen. Count

areas typically cover 15-100 ha. Late afternoon counts usually last 1-2 hours and extend until darkness or until dispersing colonial animals begin to intermingle with solitary individuals. Morning counts begin at dawn and continue 1-2 hours. Results are based on the total number of bats seen leaving or remaining in a count area (entries are excluded). When results are combined for all stations, a crude density estimate can be generated and used to extrapolate a total number of solitary animals in all similar habitat on an island. The technique suffers from a number of obvious problems. Large numbers of bats can cause observer confusion and duplicate counting of some individuals, thus the method is better suited for islands with low densities of bats. Some animals may not be active during count periods, and thus go unrecorded. Confusion between *P. tonganus* and *P. samoensis* has consistently been a problem and even experienced observers have difficulty in some situations. Substantial variation in replicated counts of this type has been noted in American Samoa, with 10 counts needed per site to stabilize mean estimates (Morrell and Craig 1995). Despite this recommendation, no surveys in the Marianas to date have replicated counts to estimate numbers.

<u>Other Methods</u>. Flying foxes have been counted on one island in the Marianas using the Variable Circular Plot (VCP) technique (Fancy et al. 1999), which is widely used for morning counts of forest birds. This method involves an observer recording all bats seen and their estimated distances during a standardized time period (usually 8 minutes) at multiple stations along a series of transects. These data allow a density estimate to be derived for each habitat. Flying foxes violate several important assumptions of the technique because 1) animals clumped in colonies are not evenly distributed across the landscape, 2) roosting individuals may frequently go undetected because they rarely vocalize and are less active during the daytime when counts are conducted, and 3) flying individuals may be recorded more than once as they move back and forth through a count area.

Population Trends

<u>Guam</u>. Woodside (1958) estimated that a maximum of 3,000 *P. mariannus* remained on Guam (540 km^2) in the late 1950s. Bat abundance declined greatly through the late 1970s, when fewer than 50 bats were estimated for the entire island and no colonies were known (Wheeler and Aguon 1978). A colony of 200-300 bats reappeared in northern Guam in 1980 and increased to about 800 bats by 1982 (Wiles 1987). Since the late 1980s, it has typically held 150-350 bats during most months of the year, with numbers increasing by 100-600 bats during the winter months due to apparent migration from Rota 60 km to the north (Wiles et al. 1995; Wiles unpubl. data). Guam's subpopulation also contains small numbers (50-75) of solitary animals scattered throughout the island. Extreme predation on juvenile bats by introduced brown tree snakes (*Boiga irregularis*) is believed to be the major problem preventing recovery of the population (Wiles 1987), which was declared endangered in 1984.

<u>Commonwealth of the Northern Mariana Islands</u>. The CNMI is comprised of 14 islands ranging in size from 1-123 km^2. The first counts of *P. mariannus* on each of these islands occurred in the late 1970s or early 1980s. Rota's (85 km^2) subpopulation held about 2,400 animals from 1986-1988, but declined to about 1,000 animals soon after Typhoon Roy in 1988

(Stinson et al. 1992). Numbers have been relatively stable since then (Worthington unpubl. data). Subpopulations on Aguiguan (7 km^2), Tinian (102 km^2), and Saipan (123 km^2) have each numbered only 25-125 bats since the late 1970s, although there is evidence that Saipan's subpopulation has increased somewhat since 1995 (Wheeler 1980; Wiles et al. 1989, 1990; Krueger and O'Daniel 1999). The nine uninhabited islands north of Saipan have been surveyed as a group only once, with a total minimum estimate of 7,450 bats made in 1983 (Wiles et al. 1989). Only two islands have been resurveyed since then. Anatahan's (32 km^2) subpopulation was found to have decreased from an estimated 2,500-3,000 bats in 1983 to about 1,900-2,150 in 1995 (Worthington et al. in prep.). Three surveys of Sarigan (5 km^2) from 1983-1999 have found bat abundance to be fairly stable at about 125-200 animals (Wiles et al. 1989; Fancy et al. 1999; Wiles unpubl. data). Illegal hunting is the most serious problem affecting bats in the CNMI. A proposal to list *P. mariannus* as threatened throughout the CNMI is currently under review by the U.S. Fish and Wildlife Service.

American Samoa. Most survey work has been done on the largest island of Tutuila (142 km^2), with lesser effort spent in the three islands of the Manu'a group (5-45 km^2). Amerson et al. (1982) made the first estimates of bat populations in 1975-1976, but failed to distinguish *P. tonganus* and *P. samoensis* as separate species. Their combined estimates for both species were 75,000 bats on Tutuila and 65,000 bats in the Manu'a islands, but these were undoubtedly overestimates. In 1987-1989, island-wide roost surveys of *P. tonganus* yielded estimates of 12,750-28,000 bats (Department of Marine and Wildlife Resources annual reports). Following Hurricane Ofa in 1990, the population declined dramatically from overhunting to about 4,500 bats (Craig et al. 1994). It dropped to about 1,030 bats after Hurricane Val in 1992 (DMWR annual reports) and a hunting ban was enacted. Two to four island-wide roost surveys of *P. tonganus* have been conducted annually since 1992. The population increased to about 5,000 bats in 1996 (Brooke 1997) and was estimated at 3,265-4,000 bats in 1997 and 1998 (Utzurrum unpubl. data). Single annual surveys of the Manu'a islands in 1990-1994 gave estimates of 33-390 bats (Department of Marine and Wildlife Resources annual reports). In 1996, two colonial roosts were located and numbers were estimated at 1,770 bats (Brooke 1997).

In the early 1980s, Cox (1983) reported extremely low numbers of *P. samoensis* in American Samoa. Cox and Tuttle (1986) estimated that 300 individuals remained on Tutuila and petitioned the U.S. Fish and Wildlife Service for endangered status. An estimate of about 1,500 animals was made by Craig et al. (1994), using data from Tutuila, with the population roughly stable from 1986-1989 (Wilson and Engbring 1992). Numbers were estimated at 700 or less bats prior to Hurricane Ofa in 1990 (Pierson et al. 1992) and at 200-400 bats after Hurricane Val in 1992 (Craig et al. 1994). Since 1995, the number of *P. samoensis* seen in dawn counts on Tutuila has remained roughly the same at about 900 animals (Brooke 1997; Utzurrum unpubl. data). The Manu'a islands' subpopulation was about 100 bats in 1996 (Brooke 1997).

References

Amerson, Jr., A. B., W. A. Whistler, and T. D. Schwaner. 1982. Wildlife and wildlife habitat of American Samoa. 2 vols. U.S. Fish and Wildlife Service, Washington, D.C.

Brooke, A. P. 1997. Fruit bat studies: *Pteropus samoensis* and *Pteropus tonganus* 1995-1996. Department of Marine and Wildlife Resources Biological Report, Pago Pago, American Samoa.

Cox, P. A. 1983. Observations on the natural history of Samoan bats. Mammalia 47:519-523.

Cox, P. A. and M. D. Tuttle. 1986. Report to the Governor, Pago Pago, American Samoa.

Craig, P., P. Trail, and T. E. Morrell. 1994. The decline of fruit bats in American Samoa due to hurricanes and overhunting. Biological Conservation 69:261-266.

Fancy, S. G., R. J. Craig, and C. W. Kessler. 1999. Forest bird and fruit bat populations on Sarigan, Mariana Islands. Micronesica 31:247-254.

Krueger, S., and D. O'Daniel. 1999. Observations of Mariana fruit bats on Tinian. Micronesica 31:367-371.

Morrell, T. E. and P. Craig. 1995. Temporal variation in fruit bats observed during daytime surveys in American Samoa. Wildlife Society Bulletin 23:36-40.

Pierson, E. D., T. Elmqvist, and P. A. Cox. 1992. The effects of Cyclone Val on areas proposed for inclusion in the National Park of American Samoa. U.S. National Park Service.

Stinson, D. W., P. O. Glass, and E. M. Taisacan. 1992. Declines and trade in fruit bats on Saipan, Tinian, Aguijan, and Rota. Pages 61-67 *in* D. E. Wilson and G. L. Graham, editors. Pacific island flying foxes: proceedings of an international conservation conference. U.S. Fish and Wildlife Service, Biological Report 90.

Wheeler, M. E. 1980. The status of the Marianas fruit bat on Saipan, Tinian, and Rota. 'Elepaio 40:109-113.

Wheeler, M.E., and C.F. Aguon. 1978. The current status and distribution of the Mariana fruit bat on Guam. Division of Aquatic and Wildlife Resources Technical Report, No. 1. Agana, Guam.

Wiles, G. J. 1987. The status of fruit bats on Guam. Pacific Science 41:148-157.

Wiles, G. J., and P. O. Glass. 1990. Interisland movements of fruit bats (*Pteropus mariannus*) in the Mariana Islands. Atoll Research Bulletin 343:1-6.

Wiles, G. J., C. F. Aguon, G. W. Davis, and D. J. Grout. 1995. The status and distribution of endangered animals and plants in northern Guam. Micronesica 28:31-49.

Wiles, G. J., A. B. Amerson, Jr., and R. E. Beck, Jr. 1990. The mammals of Tinian, Mariana Islands. Micronesica 23:167-180.

Wiles, G. J., T.O. Lemke, and N. H. Payne. 1989. Population estimates of fruit bats (*Pteropus mariannus*) in the Mariana Islands. Conservation Biology 3:66-76.

Wilson, D. E. and J. Engbring. 1992. The flying foxes *Pteropus samoensis* and *Pteropus tonganus*: status in Fiji and Samoa. Pages 74-101 *in* D. E. Wilson and G. L. Graham, editors. Pacific island flying foxes: proceedings of an international conservation conference. U.S. Fish and Wildlife Service, Biological Report 90.

Worthington, D. J., A. P. Marshall, G. J. Wiles, and C. W. Kessler. in prep. A survey of Mariana fruit bats and feral ungulates on Anatahan, Mariana Islands.

Woodside, D. H. 1958. Fish and wildlife investigation. Department of Agriculture, Agana, Guam.

Estimating Population Sizes of Hibernating Cave Bats

MERLIN D. TUTTLE[1]

[1]Bat Conservation International, PO Box 162603, Austin, TX 78716

Winter censusing of hibernating bats in caves or mines often involves entry into large, complex systems with multiple entrances and deep vertical drops. Such entry should be attempted only by those who are properly equipped and experienced in appropriate techniques and safety precautions. Local cavers often can provide invaluable assistance.

Hibernating bats typically arouse during censuses, and each arousal costs approximately 60 days worth of stored fat reserves. Therefore, it is extremely important that censuses be as brief as possible and minimize bat exposure to light and sound. Both because bats nearly always arouse to some extent, and because disturbed bats often relocate within a cave to less suitable and less accessible roosts when disturbed, human visits normally should not exceed one every second or third year and should be conducted by a minimum number of observers.

Where bats roost singly, or in small groups in easily viewed locations, they can be accurately identified and counted individually, with minimal or no handling, by an experienced person. However, in many locations, bats form clusters of varied density, often high above the floor, forcing observers to estimate numbers based on knowledge of normal clustering behavior and densities for each species. This can be quite difficult. Clusters appear smaller at greater distances, and clustering density can be highly variable. Indiana myotis vary from approximately 300 to 484 per square foot, while gray myotis range from 50 to 250. Density tends to be inversely proportional to ambient temperature, but not consistently enough to enable calculations based on temperature alone. Roughness of roost surfaces is an additional complicating factor, as is the fact that some clusters are shared by more than one species.

Even experienced researchers are only accurate within about 10-20% in estimating cluster densities. Nevertheless, at sites where bats occupy the same roosts from year to year, errors tend to be consistently in the same direction, greatly reducing their impact on calculation of status trends. Wall temperatures should be carefully recorded at consistent locations as near as possible to roosting bats, and when these change markedly, or evidence of recent disturbance is noted, bats may need to be looked for in new locations or cluster density estimates adjusted. Possible mortality also must be considered.

Hibernating bat counts can be accurate in simple caves or mines. However, the best hibernation roosts are often in structures that are large, multilevel, and complex. Bats have preferred roosting locations that may be used consistently from year to year under comparable weather and disturbance conditions, but major changes can be expected whenever either roost temperature or human disturbance change. Since some of the most important gray and Indiana myotis hibernacula include miles of multilevel passages, roost switching can result in substantial year to year errors in estimating populations.

Avoidance learning by bats is a further complicating factor. Especially if bats are censused more than once every two or three years, or if visits are prolonged, those that have options tend to move to locations researchers have not yet discovered, leading to false conclusions of decline. Because bats, especially those that are handled, learn to avoid researchers, mark and recapture techniques that rely on ratios of marked to unmarked bats, are highly unreliable in estimating population sizes. Furthermore, different sex, age, and reproductive groups of bats seldom roost randomly in hibernation, even in the largest clusters.

Although exact counts are frequently impossible, estimation of population trends is often feasible. Biases of hibernation sampling can be minimized by consistency. Censuses should be conducted on the same dates and by the same individuals as much as possible, and assumptions made at each census should be clearly recorded and held consistent among as many censuses as possible. Complex cave systems should be carefully mapped, roosting areas measured, and wall temperature profiles recorded in summer, when the bats are absent. Knowledge of the bats' requirements, combined with such data, can be invaluable when estimating cluster sizes or when locating bats that shift due to temperature changes or disturbance. Especially at complex locations, when censuses must be conducted by new individuals, they should always have a prior opportunity to accompany the previous censuser on at least one or more visits to familiarize themselves with techniques and assumptions used at that location. Both for consistency and safety, at least two persons should participate in each census.

Population Trends of Foliage-Roosting Bats

TIMOTHY C. CARTER[1], MICHAEL A. MENZEL[2], and DAVID SAUGEY[3]

[1] Department of Zoology, Southern Illinois University, Carbondale, IL 62901

[2] Division of Forestry, Wildlife and Fisheries Resources, P.O. Box 6125, Morgantown, WV 26506-6125

[3] U.S. Forest Service, Ouachita National Forest, P.O. Box 189, Jessieville, AR 71949

Introduction. Lasiurine bats have long been considered some of the most common bats (Layne 1958; LaVal and LaVal 1979; Whitaker and Hamilton 1998). However, monitoring lasiurine populations is made difficult because of their primarily solitary existence. Little is known about population trends of lasiurine bats. Examinations of past capture records can be misleading due to differences in netting intensity, duration, and net placement. Capture records and all other sources of population data currently available are only indices of population status. These indices are difficult to interpret because differences in methods used to capture bats or to report the data are often inconsistent among studies. One method that can be compared over time is an examination of limiting habitat, such as suitable roosting habitat. A review of the history of North American forests may provide an indication of current and historical status of the populations of tree roosting bats. Because this method only suggests possible population trends, there is a need to implement a system for collecting population data that directly reflects the population status of all species of lasiurine bats.

Historical Information. Surprisingly little information exists that gives an indication of past lasiurine populations. There are anecdotal reports of large aggregations of bats (Jennings 1958). However, many of the species of *Lasiurus* have never been caught in great numbers at any time in history. Most reports of captures (e.g., LaVal and LaVal 1979), do not give enough information to allow calculations of catch per unit effort for comparisons between data sets. Consequently, these reports can provide only an indication of past populations relative to other species populations. Furthermore, differences in species habitat use and differences in net placement can alter capture results at different locations, further complicating the comparison. An examination of health department records of submissions of lasiurine bats could be a good indication of population numbers over time, assuming submission rates have been constant over time.

Habitat Analysis. An alternate way to examine past population trends is to track the most limiting ecological factor over time and see how it has changed. Roosting habitat is likely the most limiting factor for this group. Roosting requirements for lasiurines vary somewhat, with the exception that they all use foliage as their primary roosting habitat. A look at how these habitats have changed over the past century should give us an indication of population trends. Prior to 1800, the effect humans had on the forests of North America was negligible. In the early 1800's, the human population in North America reached the point where the clearing of forests for agriculture became measurable. The greatest rate of clearing was during the late 1800s. The arrival of the boll weevil (*Anthonomus grandis*) in 1920 helped to end the cotton era. In addition, the advent of mechanized farm equipment lead to the stabilization of forest clearing for agriculture. This gave way to the reestablishment of many of today's forests, especially in the southeast (Williams 1989; MacCleery 1992). The increase in forestlands in the southeast has probably lead to a general increase of all foliage roosting bats in this area, relative to the late 1800's. However, human altering of forest composition and the relatively recent increase in urbanization, especially in certain habitats, has lead to changes in bat species compositions throughout this region. Red bat (*Lasiurus borealis*) and hoary bat *(L. cinereus*) populations probably have increased since the reforestation of the 1930's and 1940's, especially in the east (Shump and Shump 1982a, 1982b). Species that often use conifers such as Seminole bats *(L. seminolus*) have probably benefitted from the increase in pine plantations throughout the southeast, whereas others that use mostly deciduous or mixed forests may be negatively impacted (Shump and Shump 1982b; Wilkins 1987; Menzel et al. 1998). However, species restricted to the southern coastal states such as the northern yellow bat (*L. intermedius*) and Seminole bat may have suffered from the increase of urbanization of the coastal areas, mainly the maritime forests (Constantine 1958; Jennings 1958; Menzel et al. 1995). In addition, the collecting of Spanish moss (*Tillandsia usneoides*) for padding in car seats and matrices may have impacted both northern yellow and Seminole bat populations during the mid 1900's (Constantine 1958; Jennings 1958). The sprawling human population probably also negatively affects most other species of lasiurines to varying degrees. This increase in sprawl includes not only forest clearing for development, but also fragmentation of the remaining forests. Recent work has shown conflicting views on the effect of fragmentation on lasiurine populations. Lasiurines are fast flying insectivores, foraging mostly along edge type habitats (Farney and Fleharty 1969; Shump and Shump 1982a, 1982b). However, reports seem to suggest that some of these species prefer interior forests for roosting (Hutchinson 1998). Therefore, only limited fragmentation could be seen as beneficial for lasiurines.

Conclusion. Though little population data exist for foliage roosting bats, anecdotal data support the contention that members of this group are among the most common bats. The biggest threat for foliage roosting bats, forest clearing for agriculture, has slowed to negligible levels. Despite their relative commonness, the constant urban development of our forested lands represents the next major threat for foliage roosting bats. Population monitoring programs need to be implemented to gauge the affects of this new threat.

References

Constantine, D. G. 1958. Ecological observations on lasiurine bats in Georgia. Journal of Mammalogy 39:64-70.

Farney, J., and E. D. Fleharty. 1969. Aspect ratio, loading, wing span, and membrane areas of bats. Journal of Mammalogy 50:362-267.

Hutchinson, J. T. 1998. Summer roost site selection of red bats in mixed mesophytic forests. M.S. thesis, University of Kentucky, Lexington. 207 pp.

Jennings, W. L. 1958. The ecological distribution of bats in Florida. Ph.D. dissertation, University of Florida, Gainesville. 127 pp.

LaVal, R. K., and M. L. LaVal. 1979. Notes on reproduction, behavior, and abundance of the red bat, *Lasiurus borealis*. Journal of Mammalogy 60:209-212.

Layne, J. N. 1958. Notes on mammals of southern Illinois. American Midland Naturalist 60:219-254.

MacCleery, D. W. 1992. American forests: a history of resiliency and recovery. USDA Forest Service, FS-450 and Forest History Society, Durham, NC. 58 pp.

Menzel, M. A., T. C. Carter, B. R. Chapman, and J. Laerm. 1998. Quantitative comparison of tree roosts used by red bats (*Lasiurus borealis*) and Seminole bats (*L. seminolus*). Canadian Journal of Zoology 76:630-634.

Menzel, M. A., T. C. Carter, and D. M. Krishon. 1995. Roosting, foraging, and habitat use by bats of Sapelo Island, Georgia. Georgia Department of Natural Resources Technical Report.

Shump, K. A. Jr., and A. U. Shump. 1982a. *Lasiurus borealis*. Mammalian Species, 183:1-6.

Shump, K. A. Jr., and A. U. Shump. 1982b. *Lasiurus cinereus*. Mammalian Species, 185:1-5.

Whitaker, J. O. Jr., and Hamilton, W. J., Jr. 1998. Mammals of the eastern United States. Cornell University Press, Ithaca, New York. 583 pp.

Wilkins, K. T. 1987. *Lasiurus seminolus*. Mammalian Species 280:1-5.

Williams, M. 1989. Americans and their forests: a historical geography. Cambridge University Press, NY. 599 pp.

Surveying and Monitoring *Corynorhinus rafinesquii* and *Myotis austroriparius* in Bottomlands

Mary Kay Clark[1]

[1] North Carolina State Museum of Natural Sciences, 102 N. Salisbury Street, Raleigh, NC 27603

Bottomland hardwood swamp (BHW) systems in the southeastern United States contain some of the best remaining roosting and foraging habitat for bats of that region. These systems have a diverse bat community. Ten species are known to roost and feed in BHW: *Corynorhinus rafinesquii, Eptesicus fuscus, Lasiurus borealis, L. cinereus, L. seminolus, Lasionycteris noctivagans, Myotis austroriparius, Nycticieus humeralis, Pipistrellus subflavus,* and *T. brasiliensis* (Heitmeyer et al. 2000). Two of these, *C. rafinesquii* (Rafinesque's big-eared bat) and *M. austroriparius* (southeastern bat), are rare in the southeast and are considered to be at-risk throughout their ranges. Most states in the Southeast list both of these species in some category of concern (e.g., *C. rafinesquii* is "state threatened" in North Carolina [Clark 1999]). Radio-telemetry studies of *C. rafinesquii* and *M. austroriparius* conducted in South Carolina (Clark et al. 1997, 1998) and mist-net surveys conducted in other southeastern states (Horner and Mirowsky 1996; Cochran et al. 2000) demonstrate a close association with mature cypress-gum swamp forests, a BHW habitat type that is considered to be declining by the U.S. Geological Survey's Biological Resources Division.

More detailed studies of the bats that inhabit BHW systems are warranted due to the current pressures on these forests. Given the rarity of *C. rafinesquii* and *M. austroriparius,* and their association with a declining habitat, a high priority should be placed on survey and monitoring efforts for these two species. In particular there is a great need to gather baseline population data in order to monitor population trends. In general, survey and monitoring efforts for these two bats are nonexistent in most southeastern states. However, more attention has been directed towards these species in the last five years. Since most of these survey and monitoring efforts are recent (e.g., Texas began regular monitoring in 1994 [Horner 1994]) published literature and long-term data on population sizes are lacking.

Estimating population sizes of any bat species within a given area is problematic. Survey and monitoring efforts for tree-cavity roosting bats pose special challenges. Southeastern bats and big-eared bats are rare and are widely dispersed over a broad and sometimes physically challenging area. Methods used to find roost trees, such as radio-telemetry, are labor intensive and costly. The location and configuration of the cavity in a tree may prohibit a direct view of the bats, confounding efforts to acquire counts. Additionally, aspects of the roosting behaviors (both species are known to switch roosts frequently [Clark et al. 1998]) of these bats make it difficult to locate roosts and to count bats.

The goal of this presentation is to elicit discussion directed towards solutions to the challenges inherent in surveying and monitoring bats that roost in tree cavities. To accomplish this, this presentation will cover the following: a brief summary of existing knowledge on bats in bottomlands to place the survey and monitoring needs in an ecosystem context, a review of pertinent life history characteristics of *C. rafinesquii* and *M. austroriparius,* an overview of the survey and monitoring efforts that are in place in the southeast, and a discussion of the challenges one faces in these efforts.

References

Clark, M. K. 1999. Status accounts of the state's rare mammal fauna. Report prepared for the N. C. Wildlife Resources Commission's Nongame Advisory Committee. August 1999.

Clark, M. K., A. Black, and M. Kiser. 1998. Roosting and foraging activities of *Corynorhinus rafinesquii* and *Myotis austroriparius* in the Francis Beidler Forest in South Carolina. Paper presented at the 28th Annual Symposium on Bat Research, October 1998, Hot Springs, AR.

Clark, M. K., E. Hajnos, and A. Black. 1997. (Abstract) Radio-tracking *Corynorhinus rafinesquii* and *Myotis austroriparius* in South Carolina. Paper presented at the 27th Annual Symposium on Bat Research, October 8-11, 1997, Tuscon, AZ.

Cochran, S. M., V. E. Hoffman, J. D. Wilhide, V. R. McDaniel, and S. King. 2000. Roosting and habitat use of bats in a southern bottomland hardwood forest. *In* Ecology and Management of Bottomland Hardwood Forest Systems: The State of Our Understanding. Proceedings of a symposium conducted in Memphis, TN March 11-13, 1999. Gaylord Memorial Laboratory, Puxico, MO. In press.

Heitmeyer, M. E., M. K Clark, R. J. Cooper, and B. D. Leopold. 2000. Ecological relationships of warmblooded vertebrates in bottomland hardwood ecosystems. *In* Ecology and Management of Bottomland Hardwood Forest Systems: The State of Our Understanding. Proceedings of a symposium conducted in Memphis, TN March 11-13, 1999. Gaylord Memorial Laboratory, Puxico, MO. In press.

Horner, P. 1995. East Texas rare bat survey: 1994. Final Report (9 January 1995). Texas Parks and Wildlife Department, Resource Protection Division, Austin. 15 pp.

Horner, P. and K. Mirowsky 1996. East Texas rare bats survey: 1995. Final report (17 January, 1996). Texas Parks and Wildlife Department, Resource Protection Division, Austin. 15 pp.

Western Crevice- and Cavity-Roosting Bats

MICHAEL A. BOGAN[1], PAUL M. CRYAN [1], THOMAS J. O'SHEA[2], LAURA E. ELLISON[2], and ERNEST W. VALDEZ[1]

[1]U.S. Geological Survey, Midcontinent Ecological Science Center, Museum of Southwestern Biology, University of New Mexico, Albuquerque, NM 87131

[2]U.S. Geological Survey, Midcontinent Ecological Science Center, 4512 McMurry Ave., Fort Collins, CO 80525-3400

Pierson (1998) records 45 bat species of 19 genera and four families in the United States. Of this number she notes that there are 27 species with distributions mostly confined to the western United States, plus six species that occur in both eastern and western North America. *Myotis septentrionalis* occurs westward to British Columbia in Canada and eastern Wyoming in the United States (Bogan and Cryan 2000) and we include it as a western species. Thus, we tabulate a total of 34 species of bats that occur in the western U.S. Recent records (C. Jones pers. commun.) of *Pipistrellus subflavus* in western Texas suggest that this species should also be considered as a species of both eastern and western affinities.

Humphrey (1975) demonstrated that bat faunal size in the U.S. is correlated with the presence or absence of structures (caves, trees, buildings, rugged terrain) used for roosting. In particular, bat diversity and evenness were high in areas where all types of roost structures occur and were lower where some kinds of roosts were lacking. The more topographically diverse western U.S. has a more diverse bat fauna. Furthermore, both faunal size and community diversity vary in a geographically patchy rather than clinal fashion, suggesting little correlation with growing season or insect diversity. Humphrey (1975) suggested that high survival rates, strong site attachment, and low natality rates are all demographic adaptations of colonial species. He found a strong correlation of litter size with size of typical nursery populations and stated that species having three young are typically solitary tree-dwellers, those having twins are solitary or form nurseries of moderate size in trees, crevices, and buildings, and species having a single young occur in nursery colonies of moderate to large size, often in caves.

To obtain information on bat species that roost in crevices and cavities in rocks and trees we examined the U.S. Geological Survey Bat Population Database (BPD; Ellison et al., this volume) for records of bats using such roosts. We included use of rock shelters as well. In addition, we examined an array of recent studies, including our own, that provide new data on species known to roost in crevices or cavities in trees and rocks. Species of the western U.S. that use crevices or cavities as roosts included: *Antrozous pallidus*, *Choeronycteris mexicana*, *Corynorhinus townsendii*, *Eptesicus fuscus*, *Euderma maculatum*, *Eumops perotis*, *Idionycteris phyllotis*, *Lasionycteris noctivagans*, *Leptonycteris curasoae*, *L. nivalis*, *Myotis californicus*, *M. ciliolabrum*, *M. evotis*, *M. lucifugus*, *M. septentrionalis*, *M. thysanodes*, *M. volans*, *M. yumanensis*, *Nyctinomops femorosaccus*, *N. macrotis*, *Pipistrellus hesperus*, and *Tadarida brasiliensis*. Many of these 22 species may only use such sites opportunistically or at certain times of the year. For other species it appears that cavities and crevices are an important part of the life history of the species, especially for reproductive purposes. Variation in the type of roost used within a species is likely influenced by such factors as sex, season, and roost availability. One species, *Eumops underwoodii*, is likely to roost in crevices in cliffs, but no U.S. roosts have been described in the literature.

Categorizing species as crevice and cavity users is an artificial classification and there is the possibility that in combining them we will obscure unique and differing aspects of their life histories. Although this is undoubtedly true, there are several unifying features of these bats. Like nearly all bats north of Mexico, most species are insectivorous (three nectarivorous forms are exceptions), have low reproductive rates (0.5-1.5 young/female/yr [Geisler 1979]; notably excluding *Lasiurus* spp.), hibernate in the winter (but at least a dozen species migrate considerable distances and probably do not hibernate), exhibit delayed fertilization (sperm storage during hibernation), have long infant dependency for a small mammal (weeks to months), suffer high juvenile mortality but are relatively long-lived (average, 5-15 yrs; extreme, 30 yrs; survival rates, 50-70%; Findley 1993), and may have low rates of predation (but see Tuttle and Stevenson 1982).

Conversely, and as hinted at above, bats using cavities and crevices also represent a very diverse assemblage. For the U.S., the group includes both the smallest (*P. hesperus*) and largest (*E. perotis*) species, slow- (*P. hesperus*, several *Myotis*) and fast- (lasiurines and molossids) flying species, relatively well- (*M. lucifugus*) and poorly- (*Eumops*, *Nyctinomops*) known species, slow- (*A. pallidus*) and faster- (*M. lucifugus*; Kunz and Stern 1995) developing species, those that escape (sensu Findley 1993) food shortage in north temperate winters in time (hibernators) versus those that escape in space (migrators), and those with protein-rich diets (insectivores) and those with almost protein-free diets (nectarivores).

Western bat species also can be variable and flexible in their roosting behaviors. For example, *M. septentrionalis* uses buildings and caves, as well as several tree species (Mumford and Cope 1964; Foster 1993; Sasse 1995; Cryan et al. unpubl.); *Myotis thysanodes* is known to inhabit buildings (Dalquest 1947; Musser and Durrant 1960; Studier 1968; Cryan et al. unpubl.), rock crevices (Bogan et al. 1998), trees (Rabe et al. 1998; Cryan et al. unpubl.), mines (J. S. Altenbach personal communication), and caves (Baker 1962); *M. volans* uses buildings (Dalquest and Ramage 1946), several tree species (Baker and Phillips 1965; Vonhof and Barclay 1996; Ormsbee and McComb 1998; Rabe et al. 1998), and rock crevices (Quay 1948; Cryan et al. unpubl.); and *E. fuscus* is known to use buildings (Barbour and Davis 1969; Barclay 1991), several tree species (Brigham 1991; Vonhof and Barclay 1996; Kalcounis and Brigham 1998; Bogan et al. 1998); cactus (Cross and Huibregtse 1964); and caves and rock crevices (Barbour and Davis 1969; Barclay 1991). Such variation in roosting behavior makes the classification of species into distinct groups such as “crevice and cavity dwellers” difficult.

Yet another significant source of variation in roosting habits of this group of species is that in most species, males and females exhibit differing roosting behavior during the summer. This is because of the differing thermoenergetic demands placed on pregnant and lactating females. In brief, males are able to use periodic (usually daily) periods of torpor to lower their body temperature and hence their energy expenditure. Females, however, usually maintain a constant body temperature during pregnancy and lactation. This promotes rapid and timely growth of the fetus and young and enables young-of-the-year to acquire and store energy to meet the demands of either hibernation or migration. In practice, this often means that males tend to roost solitarily in caves, mines, under tree bark, or in buildings, whereas females appear to choose sites that retain heat (e.g., cavities in large, isolated trees and snags or crevices in exposed cliff faces) where both they and their young can maintain a more or less constant body temperature that promotes rapid growth. During the summer months, maternity groups must find larger spaces to aggregate than solitary males, likely influencing the type of structure selected. In the winter, both sexes of hibernating species likely prefer the same cool temperatures.

Historically, most information on this suite of species came from opportunistic encounters at, or in, caves, mines, bridges, tunnels, and buildings. The BPD reflects this as many species that are known to use crevices or cavities, at least seasonally, also use more “traditional” roosting sites. Not surprisingly, the BPD reveals that many instances of non-crevice roost use by these species occur in winter months (presumably during hibernation), although not exclusively so. Some of the largest population estimates for several of these species in fact comes from these observations of winter roosts. Unfortunately, as noted by Ellison et al. (this volume), there are few observations that extend over years or even months, and there are very few descriptions of winter roosts for many species of western bats that roost in crevices and cavities in summer.

Since the late 1950s, considerable information on reproduction, diet, foraging areas, activity times, associates, and the like have been obtained by capturing these species in “mist” nets set over water. Western landscapes promote this activity due to the isolation of one waterhole from another, a circumstance that may concentrate bats. This “concentration effect” likely depends on seasonal precipitation, with wet summers that produce more and closer waterholes tending to disperse bats over the landscape with consequently lower capture rates (Kenneth Geluso, pers. commun.). Most investigators agree that mist-net captures, although they provide considerable “hands-on” data, are fraught with a variety of biases and may offer few opportunities, beyond monitoring for presence and relative abundance, for long-term population monitoring. Cryan et al. (2000) noted an additional problem with mist-net captures, namely elevational variation in abundance of males and females.

Thus, for many years, population estimates of roosting bats were limited primarily to observation at caves, mines, buildings, and other roosts where the presence of bats was fairly obvious, or to relative abundance estimates obtained while mist-netting. Roost sites in crevices and cavities with no obvious outward indication of bats were vastly under represented in abundance estimates. Since the emergence of miniature radio-transmitter technology in the mid-1980's, bats have been shown to roost in a variety of structures and situations that were previously undocumented. For instance, many radio-tracking studies have been carried out in forested areas during the summer months, revealing that bats frequently form maternity colonies in trees (Barclay et al. 1988; Sasse 1995; Barclay and Brigham 1996; Campbell et al. 1996; Mattson et al. 1996; Vonhof and Barclay 1996; Brigham et al. 1997; Callahan et al. 1997; Betts

1998; Kalcounis and Brigham 1998; Ormsbee and McComb 1998; Rabe et al. 1998; Cryan et al. unpubl.). While the use of trees by bats had been documented previous to the advent of radio-transmitters (Barbour and Davis 1969), there were no practical means by which to find and survey such roosts. Similar disclosure of rock crevices used as roosts by bats have been possible with radio transmitters (Lewis 1993; Bogan et al. 1998; Cryan et al. unpubl.).

However, most work to date has involved simply characterizing such roosts, following movements of radio-tracked bats among a network of roosts, obtaining information on foraging behavior, and making counts of emerging bats. We are not aware of any current long-term population monitoring efforts of bats occupying cavities or crevices in the western U.S. Nonetheless, follow-up surveys of historically occupied bat roosts indicate the utility and importance of monitoring crevices and shelters to assess long-term population trends (e.g., Pierson and Rainey 1998; O'Shea and Vaughan 1999).

Because bats roosting in cavities or crevices are typically not visible from the outside, abundance estimates must be based on counts of the bats leaving the roost or by somehow looking into the roost. The former method is the most commonly used technique and typically involves capturing or visually observing bats as they exit the roost. Capture methods allow positive species identification and determination of colony demographics, but are invasive and may bias future monitoring. Visual emergence counts are minimally invasive, but the drawbacks to visual counts include limited light levels by the time the bats emerge, distance from roost (e.g., crevice high on cliff wall, cavity high in tree), difficulty in counting multiple bats leaving at once, and not being able to confirm species identification. Such obstacles could be minimized by using night-vision scopes, infra-red or thermal-imaging cameras, automated counting devices, and ultrasonic bat detectors (for species identification). Looking into a bat roost is a less practical way of counting bats, although recent technological developments such as miniature camera probes (Creature Peeper) may render such tasks more viable in the near future.

Given the often incidental nature of observations and lack of data on specific locations of overwintering sites, it is not clear that cavity- and crevice-dwelling bats can be monitored in a systematic fashion at their winter roosts. Certainly this will be difficult for many of the migratory species that cross international borders. Even for species that only migrate very short distances to their winter quarters we must be able to track them to such sites. Presumably, if technology provides smaller and longer-lasting transmitters in the future, it may then be feasible to track some species from summer to winter quarters. Likewise, development of remote-monitoring methods may allow censuses of some species in roosts that cannot or should not be entered in the winter. Once roosts locations are known, it is feasible to contemplate the establishment of a long-term monitoring program, assuming funding for such activities is available. In the meantime some level of continued inventory for new roost locations may be required.

A major obstacle confounding any attempt to assess the abundance of crevice or cavity roosting bats, at least during the summer months, is the fact that many species change roosts frequently. Lewis (1995) discussed aspects of roost fidelity and noted that costs of short-term movement (of bats among roosts) should be balanced by benefits associated with moving. She found that of 43 species with such data available worldwide, 25 frequently change roosts, 14 rarely change, and 4 show intraspecific variability in fidelity. She concluded that roost fidelity is directly related to roost permanency and inversely related to roost availability. The presumed benefits of fidelity include greater site familiarity, maintenance of social relationships, and retention of roosts suited for raising offspring. Conversely, the benefits of lability include decreased commuting costs to foraging areas, familiarity with roosts that may differ in microclimate, and possible lower probability of predation and parasitism. In some studies where tree cavity-roosting bats switched roosts frequently, the distance between subsequently used trees was short, suggesting the existence of colony fidelity to specific groups of trees or relatively small areas within a forest (Vonhoff and Barclay 1996; Callahan et al. 1997; Kalcounis and Brigham 1998; Cryan et al. unpublished).

In relation to caves and mines, cavities and crevices in trees and rock are generally less permanent and may be locally more abundant, likely influencing bats roosting in such structures to move frequently. Problems associated with monitoring roosts used by roost-switching bats are obvious. If there are 50 potential roost crevices in an area and only one observer, how can monitoring occur? Currently there are too many unanswered questions regarding basic natural history of roost-switching bats to competently proceed with monitoring of such populations. Important topics to address include determining the seasonal movements and interactions of roost-changing bats in a given area and how these factors vary with locality.

References

Baker, J. K. 1962. Notes on the *Myotis* of the Carlsbad Caverns. Journal of Mammalogy 48:270-286.

Baker, R. H., and C. J. Phillips. 1965. Mammals from El Nevado de Colima, Mexico. Journal of Mammalogy 46:691-693.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. The University Press of Kentucky, Lexington, KY. 286 pp.

Barclay, R. M. R. 1991. Population structure of temperate zone insectivorous bats in relation to foraging behavior and energy demand. Journal of Animal Ecology 60:165-178.

Barclay, R. M. R., and R. M. Brigham, editors. 1996. Bats and forests symposium, October 19-21, 1995, Victoria, British Columbia, Canada. Research Branch, British Columbia Ministry of Forestry, Victoria, British Columbia, Working Paper 23/1996. 292 pp.

Barclay, R. M. R., P. A. Faure, and D. R. Farr. 1988. Roosting behavior and roost selection by migrating silver-haired bats (*Lasionycteris noctivagans*). Journal of Mammalogy 69:821-825.

Betts, B. J. 1998. Roosts used by maternity colonies of silver-haired bats in northeastern

Oregon. Journal of Mammalogy 79:643-650.

Bogan, M. A., and P. M. Cryan. 2000. Bats of Wyoming. *In* J. R. Choate, editor. Fort Hays Studies in Zoology, Editor. Fort Hays State University, Hays, KS. In press.

Bogan, M. A., T. J. O'Shea, P. M. Cryan, A. M. Ditto, W. H. Schaedla, E. W. Valdez, and K. T. Castle. 1998. A study of bat populations at Los Alamos National Laboratory and Bandelier National Monument, Jemez Mountains, New Mexico. Los Alamos National Laboratory, LA-UR-98-2418.

Brigham, R. M. 1991. Flexibility in foraging and roosting behavior by the big brown bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69:117-121.

Brigham, R. M., M. J. Vonhof, R. M. R. Barclay, and J. C. Gwilliam. 1997. Roosting behavior and roost-site preferences of forest-dwelling California bats (*Myotis californicus*). Journal of Mammalogy 78:1231-1239.

Callahan, E. V., R. D. Drobney, and R. L. Clawson. 1997. Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri. Journal of Mammalogy 78:818-825.

Campbell, L. A., J. G. Hallett, and M. A. O'Connell. 1996. Conservation of bats in managed forests: use of roosts by *Lasionycteris noctivagans*. Journal of Mammalogy 77:976-984.

Cross, S. P., and W. Huibregtse. 1964. Unusual roosting site of *Eptesicus fuscus*. Journal of Mammalogy 45:628.

Cryan, P. M., M. A. Bogan, and J. S. Altenbach. 2000. The effect of elevation on the distribution of female bats in the Black Hills, South Dakota. Journal of Mammalogy. In press.

Cryan, P. M., M. A. Bogan, and G. M. Yanega. Roosting habits of four bat species in the Black Hills of South Dakota. Unpublished manuscript, 22 pp.

Dalquest, W. W. 1947. Notes on the natural history of the bat *Corynorhinus townsendii* in California. Journal of Mammalogy 28:17-30.

Dalquest, W. W., and M. C. Ramage. 1946. Notes on the long-legged bat (*Myotis volans*) at Old Fort Tejon and vicinity, California. Journal of Mammalogy 27:60-63.

Findley, J. S. 1993. Bats: a community perspective. Cambridge University Press, Cambridge, UK. 179 pp.

Foster, R. W. 1993. Roost site selection by the northern bat (*Myotis septentrionalis*). Bat Research News 34:108.

Geisler, J. 1979. Ecology of bats. Pages 281-342 *in* D. M. Stoddart, editor. Ecology of small mammals. Chapman and Hall. London.

Humphrey, S. R. 1975. Nursery roosts and community diversity of Nearctic bats. Journal of Mammalogy 56:321-346.

Kalcounis, M. C., and R. M. Brigham. 1998. Secondary use of aspen cavities by tree-roosting big brown bats. Journal of Wildlife Management 62:603-611.

Kunz, T. H., and A. A. Stern. 1995. Maternal investment and post-natal growth in bats. Pages 123-138 *in* P. A. Racey and S. M. Swift, editors. Ecology, evolution and behaviour of bats. Zoological Society of London. Clarendon Press, Oxford.

Lewis, S. E. 1993. Roosting and social ecology of pallid bats (*Antrozous pallidus*) in central Oregon. Ph.D. dissertation, University of Minnesota, St. Paul. 157 pp.

Lewis, S. E. 1995. Roost fidelity in bats: a review. Journal of Mammalogy 76:481-496.

Mattson, T. A., S. W. Buskirk, and N. L. Stanton. 1996. Roost sites of the silver-haired bat (*Lasionycteris noctivagans*) in the Black Hills, South Dakota. Great Basin Naturalist 56:247-253.

Mumford, R. E., and J. B. Cope. 1964. Distribution and status of the Chiroptera of Indiana. American Midland Naturalist 72:473-489.

Musser, G. G., and S. D. Durrant. 1960. Notes on *Myotis thysanodes* in Utah. Journal of Mammalogy 41:393-394.

Ormsbee, P. C., and W. C. McComb. 1998. Selection of day roosts by female long-legged myotis in the central Oregon Cascade range. Journal of Wildlife Management 62:596-603.

O'Shea, T. J., and T. A. Vaughan. 1999. Population changes in bats from central Arizona: 1972 and 1997. Southwestern Naturalist. In press.

Pierson, E. D. 1998. Tall trees, deep holes, and scarred landscapes: conservation biology of North American bats. Pages 309-325 *in* T. H. Kunz and P. A. Racey, editors. Bat biology and conservation. Smithsonian Institution Press, Washington, D.C.

Pierson, E. D., and W. E. Rainey. 1998. Distribution, habitat associations, status, and survey methodologies for three molossid bat species (*Eumops perotis, Nyctinomops femorosaccus, Nyctinomops macrotis*) and the vespertilionid Euderma maculatum. Final Report, Contract #FG2328WM, California Department of Fish and Game, 61 pp.

Quay, W. B. 1948. Notes on some bats from Nebraska and Wyoming. Journal of Mammalogy 29:181-182.

Rabe, M. J., T. E. Morrell, H. Green, J. C. DeVoss, Jr., and C. R. Miller. 1998. Characteristics of ponderosa pine snag roosts used by reproductive bats in northern Arizona. Journal of Wildlife Management 62:612-621.

Sasse, D. B. 1995. Summer roosting ecology of cavity-dwelling bats in the White Mountain National Forest. M. S. Thesis, University of New Hampshire, Durham. 65 pp.

Studier, E. H. 1968. Fringe-tailed bat in northeast New Mexico. Southwestern Naturalist 13:362.

Tuttle, M. D., and D. Stevenson. 1982. Growth and survival of bats. Pages 105-150 *in* T. H. Kunz, editor. Ecology of bats. Plenum Publishing Corporation. New York.

Vonhof, M. J., and R. M. R. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74:1797-1805.

Bat Colonies in Buildings

THOMAS H. KUNZ[1] and D. SCOTT REYNOLDS[1]

[1] Department of Biology, Boston University, Boston, Massachusetts 02215, USA

Many species of bats have successfully adapted to man-made structures for roosting. Of the 45 species of bats known from North America (north of Mexico), more than half are known to use buildings as roosts for at least part of the year. Buildings, mostly of European-style architecture, offer a rich variety of internal and external roosting sites for bats. The interior spaces in houses, church attics, barns, schools, and similar structures have become substitutes for natural tree cavities. Thus, it is not surprising that so many bat species exploit buildings as roosts. Spaces beneath tile and corrugated metal and fiberglass roofs, spaces beneath wooden shingles, and darkened areas behind shutters also provide substitutes for natural roosts such as crevices and exfoliating bark of trees.

The widespread use of both old and new buildings as substitutes for natural roosts suggests that bats are capable of rapidly exploiting many different kinds of man-made structures. A variety of bats are associated with buildings both in temperate and tropical regions. In North America, the big brown bat (*Eptesicus fuscus*), little brown myotis (*Myotis lucifugus*), and the Yuma myotis (*M. yumanensis*) have so completely adapted to buildings during the warm months, especially during the maternity period, that there are few historical records of these species occurring in natural roosts. Several other North American species, including the evening bat (*Nycticeius humeralis*), the Mexican free-tailed bat (*Tadarida brasiliensis*), eastern pipistrelle (*Pipistrellus subflavus*), cave myotis (*Myotis velifer*), southeastern myotis (*M. austroriparius*), northern long-eared myotis (*M. septentrionalis*), western long-eared bat (*Corynorhinus townsendii*), and the pallid bat (*Antrozous pallidus*) regularly roost in buildings. In fact, *Myotis velifer* and *Tadarida brasiliensis* have both expanded their distributions beyond the limits of karst regions in North America, where they now occupy a wide range of man-made structures. In Texas alone, populations of *T. brasiliensis* have increased as much as 15 percent above numbers recorded before modern building construction. The exploitation of buildings by *M. lucifugus* has made it possible for this species to expand its distributional range into otherwise uninhabitable regions of North America.

Although the extensive use of buildings has probably contributed to increased numbers of some species, other activities of humans, such as widespread pesticide use and deforestation has been detrimental to both roosting and feeding success of bats. Extensive deforestation have had a profound impact on the availability of natural roosting sties, particularly by depleting the availability of natural tree cavities. Additionally, considerable public pressure has been imposed to eliminate bats that roost in buildings, largely out of largely fear of exposure to rabies. Additionally, building restoration and home-energy conservation have eliminated many roosts previously available to bats in buildings. The use of chemicals as wood preservatives, treatment of buildings for wood-boring insects, and applications of toxic chemicals and repellants to exterminate bats has altered roost sites and often reduced or extirpated colonies of several species.

Some North American species may occupy buildings year-round. The common and widespread big brown bat, *Eptesicus fuscus*, is known to roost in building throughout the year-often occupying one structure during the maternity period and another during hibernation. In subtropical regions of the United States (parts of Florida, Alabama, and Louisiana and Texas), *T. brasiliensis*, also occupies buildings year-round. Similarly, in Florida and Louisiana, *P. subflavus*, and *M. austroriparius*, *Molossus molossus*, and *Nycticeius humeralis* roost in buildings year-round.

Many North American bats also exploit buildings as temporary shelters--primarily as night roosts and feeding roosts. Darkness, shelter from the wind and rain, proximity to feeding areas, and reduced risks of predation probably are primary factors that govern the selection of these temporary shelters. Bats often select such shelters in abandoned and occupied houses, barns, sheds, porches, breezeways, and garages. Inside buildings, these bats roost along the ridgepole of barns and houses, in mortises, beneath flooring boards, in spaces between bricks and wood, inside fiberglass insulation, beneath burlap bags, behind hanging pictures and mirrors, behind curtains and drapes, beneath hanging clothes, and in wood crevices. Bats also roost in spaces on the exterior of buildings, such as beneath facing boards, crevices adjacent to brick and stone chimneys, between screened and louvered vents, between windows and screens, in boxed cornices, and beneath shutters and weathered clapboards and shingles. In North America, *E. fuscus*, *M. lucifugus*, and *P. subflavus* are perhaps the best-studied species that routinely roost in buildings.

Eptesicus fuscus typically forms maternity colonies ranging from a few dozen upwards to several hundred individuals. In eastern North America, this species typically forms colonies in buildings where they give births to twins in mid-June, whereas in western North America, this bat gives birth to singletons and more commonly roosts in tree cavities. Among populations that roost in buildings, females may roost in open areas along the ridgepole, but most colonies roost in enclosed spaces, such as boxed cornices, wall spaces, and small crawl spaces in attics, that are inaccessible to observers. Males are usually segregated from females during the summer and usually roost alone during this period during the day--often beneath shutters and weathered shingles.

Maternity colonies in *M. lucifugus* typically range in size from a few hundred to several thousand individuals. Adult males of this species also are segregated from females during summer months. Females and their pups most often roost in open areas along the ridgepole of buildings, or sometimes in crevices, but seldom roost together as one compact cluster. Such clusters are more likely to be observed on cool days, whereas on warm days the bats may disperse into small, scattered groups. As with *E. fuscus*, males of *M. lucifugus* are solitary in summer. Buildings that house maternity colonies may house several adult males, but they do not roost with females, and more often than females are found roosting alone in small crevices in cooler parts of the building.

Maternity colonies of *P. subflavus* are less well known, although this species also roosts in buildings during the warm months throughout its range. The sizes of maternity colonies range from a few dozen up to 60 adults. The colony may double or triple in size at the time the twin pups are born. Adult males are solitary and seldom if ever have been observed roosting in the same building as females. This bat seeks shelter in small wood mortises and along the ridgepole of barns. Because colony size is relatively small, *P. subflavus* tends to aggregate into one or two distinct maternity clusters--although during warm spells individuals may disperse and roost with considerable space between individuals.

The roosting habits of these and other species that occupy buildings pose special challenges for estimating numbers of bats present. It may be possible to estimate the number of *E. fuscus* present in maternity colonies based on roost counts-especially when the colony forms one or two discrete clusters on the ridgepole, but most roosting situations require emergence counts. Because *E. fuscus* maternity colonies seldom exceed 200 individuals, emergence counts can be made successfully as long as all exit openings can be monitored. Typically, individual *E. fuscus* emerge from roost sites by crawling through a few small crevices. With a limited number of observers it may be possible to count all of the bats present. However, some colonies may use several alternative roost sites during the warm months, including those in nearby buildings, independent of disturbance from humans. Thus, unless observers are aware of this behavior, one could conclude that bats were not consistently present. This situation highlights the need for investigators to be aware of the possibility of alternate roosts when designing a census study.

Estimating the number of females at maternity roosts of *M. lucifugus* pose similar problems to those encountered in estimating numbers of *E. fuscus*. Because *M. lucifugus* seldom form one discrete cluster, estimates of numbers of bats present based on roost counts are impractical. This often departs from buildings by crawling though crevices, but sometimes they fly through open windows or doorways. Compared to *E. fuscus*, *M. lucifugus* is less likely to move among alternate roosts in different buildings. Emergence counts are practical if the number of exit portals are limited or can be reduced.

Maternity colonies of bats should be censused at a time of year to account for the maximum number of adults present. This can be accomplished by making back-to-back counts on three nights during the mid-lactation period, before young become volant. If additional time is available for censusing, investigators should consider making emergence counts after young bats have become volant, but before adults have emigrated. However, given the span over which young *E. fuscus* and *M. lucifugus* are born and weaned (~ 3 weeks), it is possible that some females may have already emigrated before the last pup becomes volant. Thus, emergence counts made after all young have become volant may not yield reliable estimates of the total number of adults and pups present at the colony.

Over the past 10 years we have surveyed building colonies of bats in New England, known to us from the literature, unpublished records (field notes of Hal Hitchcock and Don Griffin), and our own field notes and records. To date, we have documented records of over 600 building colonies in Massachusetts alone. Similar roost surveys are underway at building colonies from other New England States. The most frequently encountered colonies are *Myotis lucifugus*, followed by *Eptesicus fuscus*, *M. septentrionalis*, and *Pipistrellus subflavus*. Many of the roost sites that were present 40 to 50 years ago no longer exist, although several new sites have been created with the development of new buildings.

Suggested References

Anthony, E. L. P, M. H. Stack, and T.H. Kunz. 1981. Night roosting and the nocturnal time budget of the little brown bat, *Myotis lucifugus*: effects of reproductive status, prey density, and environmental conditions. Oecologia 51: 151-156.

Burnett, C. D., and P. V. August 1981. Time and energy budgets for dayroosting in a maternity colony of *Myotis lucifugus*. Journal of Mammalogy 62:758-766.

Fenton, M. B. and R. M. R. Barclay. 1980. *Myotis lucifugus*. Mammalian Species 142:1-8.

Horn, J. W. 1998. Individual variation in the nightly time budgets of the little brown bat, *Myotis lucifugus*. M.A. thesis. Boston University, Boston. 64 pp.

Hoying, K. M., and T. H. Kunz. 1998. Variation in the size at birth and post-natal growth in the insectivorous bat *Pipistrellus subflavus* (Chiroptera: Vespertilionidae). Journal of Zoology, London 245:15-27.

Fujita, M., and T. H. Kunz. 1984. *Pipistrellus subflavus*. Mammalian Species 228:1-6.

Kunz, T. H. 1982. Little brown bat. Pages 124-126 *in* D. E. Davis, Jr., editor. Census methods for birds and mammals. CRC Press, Boca Raton, FL.

Kunz, T. H. 1982. Roosting ecology of bats. Pages 1-50 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, NY.

Kunz, T. H., and E. L. P. Anthony. 1996. Variation in the timing of nightly emergence behavior in the little brown bat, *Myotis lucifugus* (Chiroptera: Vespertilionidae). Pages 225-235 *in* H. H. Genoways and R. J. Baker, editors. Contributions in mammalogy: a memorial volume honoring Dr. J. Knox Jones, Jr. Museum of Texas Tech University, 315 pp.

Kurta, A., and R. H. Baker. 1990. *Eptesicus fuscus*. Mammalian Species 356: 1-10.

Winchell, J. M., and T. H. Kunz. 1996. Day roosting activity budgets of the eastern pipistrelle bat, *Pipistrellus subflavus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 74:431-441.

Current Status of Pollinating Bats in the Southwestern United States

THEODORE H. FLEMING[1], TIM TIBBITTS[2], YAR PETRYSZYN[3] and VIRGINIA DALTON[4]

[1] Department of Biology University of Miami, Coral Gables, FL 33124

[2] U.S. National Park Service Organ Pipe Cactus National Monument Route 1, Box 100 Ajo, AZ 85321

[3] Department of Ecology and Evolutionary Biology, University of Arizona Tucson, AZ 8512

[4] Pima Community College Tucson, AZ 85709

Three species of phyllostomid bats, *Leptonycteris curasoae*, *L. nivalis*, and *Choeronycteris mexicana*, are important pollinators of columnar cacti and paniculate agaves in the arid Southwest. Females (and a few males) of these species migrate north from central (*L. nivalis*) and south-central Mexico (*L. curasoae*) each spring or early summer. *L. curasoae* forms maternity roosts in southwestern Arizona; *L. nivalis* forms post maternity roosts in southern Texas and southwestern New Mexico; and *C. mexicana* forms maternity roosts in small colonies scattered throughout southern Arizona. Presumed population declines in both species of *Leptonycteris* during the 1960's and 1970's resulted in their being declared “endangered” in 1988.

In this paper, we review recent data on the population status of these species. In the past decade, considerable effort has been expended on documenting population trends in *L. curasoae* in Arizona and Sonora, Mexico. Annual (or more frequent) exit censuses have been conducted at two caves in Sonora and one cave and two mines in southern Arizona. These data indicate that although roost sizes vary somewhat from year to year, there is no evidence of a secular population decline in this species in the northern part of its range. They further indicate that the size of northern populations of *L. curasoae* were grossly underestimated during USFWS surveys in the early 1980s. Far less information is available for the other two species of nectar-feeding bats. We recommend that systematic surveys of sites known to harbor *L. nivalis* and *C. mexicana* be conducted annually.

Appendix 1. Workshop Agenda

SUNDAY SEPTEMBER 19

6:00-7:00 PM Dinner

7:00 PM Welcome, introductions, review of workshop objectives and format (Conveners, Steering Committee)

7:30 PM Plenary Address. Introduction to Bats of the United States. Merlin Tuttle, Bat Conservation International, Austin, Texas

MONDAY SEPTEMBER 20

7:00-8:00 AM Breakfast

8:00 AM Brief reminder of objectives, announcements, explanation of full meeting format.

8:15-08:45 Methods for Estimating Numbers of Bats: Challenges, Problems, and Sampling Biases. Thomas H. Kunz, Department of Biology, Boston University, Boston, Massachusetts

8:45-09:15 Monitoring Bat Populations for Conservation: The United Kingdom National Bat Monitoring Program. Allyson Walsh and Colin Catto, The Bat Conservation Trust, London, England

9:15-09:45 Existing Data on U.S. Bat Populations. Laura E. Ellison, Thomas J. O'Shea, Michael A. Bogan, A. Lance Everette, and D. M. Schneider, U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, Colorado and Albuquerque, New Mexico

9:45-10:15 A Critical Look at National Monitoring Programs for Birds and Other Wildlife Species. John R. Sauer, Patuxent Wildlife Research Center, Laurel, Maryland

10:15-10:35 Break

10:35-10:55 Warm Season Colonies of Free-tailed Bats (*Tadarida brasiliensis*). Gary McCracken, University of Tennessee, Knoxville, Tennessee

10:55-11:15 Censusing Pacific Island Flying Foxes: A Review of Count Methods and Recent Population Trends. Gary J. Wiles, Division of Aquatic and Wildlife Resources, Guam; Anne P. Brooke, Newfield, New Hampshire; Ruth C. B. Utzurrum, Department of Marine and Wildlife Resources, American Samoa, David J. Worthington, Capitol Reef National Park, Torrey, Utah; and W. E. Rainey, University of California, Berkeley

11:15-11:35 Estimating Population Sizes of Hibernating Cave Bats. Merlin Tuttle, Bat Conservation International, Austin, Texas

11:35-11:55 Population Trends of Foliage-Roosting Bats. Timothy C. Carter, Southern Illinois University, Carbondale; Michael A. Menzel, Division of Forestry, Wildlife and Fisheries Resources, Morgantown, West Virginia; and David Saugey, U.S. Forest Service, Jessieville, Arkansas

11:55-1:15 PM Lunch

1:15-1:35 Surveying and Monitoring *Corynorhinus rafinesquii* and *Myotis austroriparius* in Bottomlands. Mary Kay Clark, North Carolina State Museum of Natural Sciences, Raleigh, North Carolina

1:35-1:55 Western Crevice and Cavity-Roosting Bats. Michael A. Bogan, Paul M. Cryan, Thomas J. O'Shea, Laura E. Ellison, and Ernest W. Valdez, U.S. Geological Survey, Midcontinent Ecological Science Center, Albuquerque, New Mexico and Fort Collins, Colorado

1:55-2:15 Bat Colonies in Buildings. Thomas H. Kunz and D. Scott Reynolds, Department of Biology, Boston University, Boston, Massachusetts.

2:15-2:35 Current Status of Pollinating Bats in the Southwestern United States. Theodore H. Fleming, University of Miami, Coral Gables, Florida; Tim Tibbitts, Organ Pipe Cactus National Monument, Ajo, Arizona; Yar Petryszyn, University of Arizona, Tucson; and Virginia Dalton, Pima Community College, Tucson, Arizona

2:35-3:00 Break

3:00 - 5:00 *Panel Discussion*, including interaction with the floor. Discussion will center around major topic areas and groupings of issues that correspond to those assigned to workshop break-out groups and to the statement of objectives. Don E. Wilson of the Smithsonian Institution will serve as panel moderator. Other panel members to include: David Anderson and Kenneth Burnham, Colorado Cooperative Fish and Wildlife Research Unit; Thomas H. Kunz, Boston University; John Sauer, Patuxent Wildlife Research Center; Allyson Walsh, U.K. National Bat Monitoring Programme; and Gary C. White, Colorado State University.

5:00 -- 7:00 Dinner

7:00 Review of Terms of Reference, Working Group Assignments

<u>TUESDAY SEPTEMBER 21</u>

7:00 -- 8:00 AM Breakfast

8:00 -- 12:00 Working Groups in Session

8:00 -- 10:00 Working Group A: Seminar on capture-recapture methods of population estimation. Gary White, David Anderson, Ken Burnham.

12:00 -- 1:30 PM Lunch, Meeting of Working Group Leaders with Steering Committee to Clarify Directions, Review Progress Made in Morning Sessions

1:30 -- 6:00 Working Groups in Session

5:00 -- 9:00 Mixer, Barbeque

<u>WEDNESDAY SEPTEMBER 22</u>

7:00 -- 8:00 AM Breakfast

8:00 -- 12:00 Working Groups in Session

12:00 -- 1:30 PM Lunch

2:30 -- 4:30 All Participants Convene and Working Group Leaders Report to Floor (This overview of each group's findings will allow fine-tuning and cross-referencing of reports, to be completed afterwards as needed.)

6:00 -- 7:30 Dinner

7:30-- Working Groups in Session

<u>THURSDAY SEPTEMBER 23</u>

7:00 - 8:30 AM Breakfast

Working Groups complete reports

Check-out at 11:00 AM

Appendix 2. Workshop Participants

David Anderson
Cooperative Fish & Wildlife Research Unit
Colorado State University
201 Wagar Building
Fort Collins, CO 80523-1484
Phone: (970) 491-5396
Fax: (970) 491-1413
Email: anderson@cnr.colostate.edu

Michele Banowetz
USGS, BRD
4512 McMurry Avenue
Fort Collins, CO 80525
Phone: (970) 226-9301
Fax: (970) 226-9230
Email: michele_banowetz@usgs.gov

Robert Berry
Brown-Berry Biological Consulting
134 Wilkes Crest Road
Bishop, CA 93514
Phone: (760) 387-2005
Fax: (760) 387-2015
Email: bobpatbat@aol.com

Michael A. Bogan
(Co-chair Steering Committee)
U.S. Geological Survey-MESC
University of New Mexico
Museum of Southwestern Biology
Albuquerque, NM 87131
Phone: (505) 346-2870 X12
Fax: (505) 346-2870 X18
Email: mbogan@unm.edu

Anne Brooke
PO Box 102
Newfields, NH 03856
Phone: (603) 772-4005
Email: apbrooke@aol.com or
abrooke@nh.ultranet.com

Pat Brown
UCLA/Brown-Berry Biological Consulting
134 Wilkes Crest Road
Bishop, CA 93514
Phone: (760) 387-2005
Fax: (760) 387-2015
Email: patbobbat@aol.com

Kenneth P. Burnham
Cooperative Fish & Wildlife Research Unit
Colorado State University
201 Wagar Building
Fort Collins, CO 80523-1484
Phone: (970) 491-5396
Fax: (970) 491-1413

Tim Carter
Department of Zoology
Southern Illinois University
Carbondale, IL 62901
Phone: (618) 453-4124
Fax: (618) 453-2806
Email: tcarter@siu.edu or
tcarter@globaleyes.net

Norita Chaney
U.S. Geological Survey
Biological Resources Division
300 National Center, Room 1C215
12201 Sunrise Valley Drive
Reston, VA 20192
Phone: (703) 648-4082
Fax: (703) 648-4238
Email: norita_chaney@usgs.gov

Alice Chung-MacCoubrey
U.S. Forest Service Rocky Mountain Research Station
2205 Columbia SE
Albuquerque, NM 87106-3222
Phone: 505-766-2384
Fax: 505-766-1046
Email: achung/rmrs_albq@fs.fed.us

Mary Kay Clark
(Steering Committee)
(Chair, Southeastern Bat Diversity Network)
Curator of Mammals
NC State Museum of Natural Science
P.O. Box 29555
Raleigh, NC 27626
Phone: (919) 715-2599
Fax: (919) 715-2614
Email: mkclark@ncdial.net (work)

Rick Clawson
Missouri Department of Conservation
1110 S. College Avenue
Columbia, MO 65201
Phone: (573) 882-9880 X3241
Fax: (573) 882-4517
Email: clawsr@mail.conservation.state.mo.us

Paul Cryan
U.S. Geological Survey-MESC
University of New Mexico
Museum of Southwestern Biology
Albuquerque, NM 87131
Phone: (505) 346-2870
Fax: (505) 277-0304
Email: myotis43@unm.edu

Virginia Dalton
Department of Wildlife and Fisheries Science
University of Arizona
Tucson, AZ 85721
Phone: (520) 743-3941
Email: plecotus@aol.com

Laura Ellison
(Steering Committee)
U.S. Geological Survey-MESC
4512 McMurry Avenue
Fort Collins, CO 80525-3400
Phone: (970) 226-9494
Fax: (970) 226-9230
Email: laura_ellison@usgs.gov

Steve Fancy
National Park Service
National Inventory & Monitoring Program
1201 Oakridge Drive
Fort Collins, CO 80525-4489
Phone: (970) 225-3571
Fax: (970) 225-3585
Email: steven_fancy@nps.gov

Ted Fleming
Department of Biology
University of Miami
Coral Gables, FL 33124
Phone: (305) 284-6881
Fax: (305) 284-3039
Email: tfleming@umiami.ir.miami.edu

Jeff Gore
Florida Game & Freshwater Fish Commission
3911 Highway 2321
Panama City, FL 32409
Phone: (850) 265-3677
Fax: (850) 747-5690
Email: gorej@gfc.state.fl.us

Leanne Hanson
USGS-BRD
PO Box 25046 - MS 300
Denver CO 80225
Phone: (303) 236-2730 X275
Fax: (303) 236-2733
Email: leanne_hanson@usgs.gov

John Hayes
Department of Forest Science
Richardson Hall
Corvallis, OR 97331-7501
Phone: (541) 737-6589
Fax: (541) 737-1393
Email: hayesj@fsl.orst.edu

Mike Herder
USDI BLM Arizona Strip
345 E. Riverside Drive
St. George, UT 84790
Phone: (435) 688-3239
Fax: (435) 688-3258
Email: michael_herder@blm.gov

Joseph Kath
(Steering Committee)
(Chair, NE Regional Bat Working Group)
Illinois Department of Natural Resources
Division of Natural Heritage
524 South Second St.
Springfield, IL 62701-1787
Phone: (217) 785-8774
Fax: (217) 785-8277
Email: jkath@dnrmail.state.il.us

Thomas Kunz
(Steering Committee)
Department of Biology
Boston University
5 Cummington Street
Boston, MA 02215
Phone: (617) 353-2474
Fax: (617) 353-5383
Email: kunz@bu.edu

Allen Kurta
Eastern Michigan University
Department of Biology
Ypsilanti, MI 48197
Phone: (734) 487-1174
Fax: (734) 487-9235
Email: bio_kurta@online.emich.edu

Gary McCracken
University of Tennessee
Dept. of Ecology & Evolutionary Biology
569 Dabney Hall
Knoxville, TN 37996
Phone: (409) 847-9334
Fax: (409) 845-3786
Email: gmccrack@utk.edu

Rodrigo Medellin
Instituto de Ecologia
UNAM
Ap. Postal 70-275
04510 Mexico, D.F.
Phone: (525) 622-9042
Email:
medellin@miranda.ecologia.unam.mx

Michael A. Menzel
Division of Forestry
West Virginia University
Morgantown WV 26506
Phone: (304) 284-9778
Email: mamenzel1@juno.com

Kirk Navo
(Steering Committee)
Colorado Division of Wildlife
0722 S. 1 E.
Monte Vista CO 81144
Phone: 719-587-6906
Fax: 719-587-6934
Email: kirk.navo@state.co.us or
navok@amigo.net

Thomas J. O’Shea
(Co-chair Steering Committee)
U.S. Geological Survey-MESC
4512 McMurry Avenue
Fort Collins, CO 80525
Phone: (970) 226-9397
Fax: (970) 226-9230
Email: tom_o’shea@usgs.gov

Mike Rabe
Arizona Game and Fish
1901 N. Kachina
Flagstaff, AZ 86001
Phone: (520) 774-0580
Email: mrabe@flagstaff.az.us

Paul Racey
Department of Zoology
University of Aberdeen
Tillydrone Avenue
Aberdeen AB24 2TZ
Phone: 01224 272858
Fax: 01224 272396
Email: p.racey@abdn.ac.uk

David Saugey
U.S. Forest Service-Jessieville Ranger Dist.
PO Box 189
Jessieville, AR 71949
Phone: (501) 984-5313
Fax: (501) 984-6253
Email: dsaugey/r8_ouachita_jessieville@
fs.fed.us

John R. Sauer
USGS-Patuxent Wildlife Research Center
11510 American Holly Drive
Laurel, MD 20708-4017
Phone: (301) 497-5662
Fax: (301) 497-5666
Email: john_r_sauer@usgs.gov

Merlin Tuttle
(Steering Committee)
Bat Conservation International
P.O. Box 162603
Austin, TX 78716
Phone: (512) 327-9721
Fax: (512) 327-9724
Email: pmeckel@batcon.org

Ruth Utzurrum
Dept. of Marine and Wildlife Resources
PO Box 3730
Pago Pago, AS 96799
Phone: 011- (684) 633-4456
Fax:011-(684) 633-5944
Email: josrbu@samoatelco.com

Ernest Valdez
U.S. Geological Survey-MESC
Museum of Southwestern Biology
University of New Mexico
Albuquerque, NM 87131
Phone: (505) 346-2870 X13
Fax: (505) 346-2870 X18
Email: ernie@unm.edu

Allyson Walsh
The Bat Conservation Trust
15 Cloisters House
8 Battersea Park Road
London SW8 4BG
Phone: 0171-627-5912
Fax: 0171-627-2628
Email: allywalsh@bct.demon.co.uk OR
awalsh@bats.org.uk

Gary C. White
Colorado State University
211B Wagar Building
Fort Collins, CO 80523
Phone: (970) 491-6678
Email: gwhite@cnr.colostate.edu

Gary J. Wiles
Division of Aquatic and Wildlife Resources
192 Dairy Road
Mangilao, GU 96923 USA
Phone: 671-735-3957
Email: gwiles@ns.gu

Don E. Wilson
Smithsonian Institution
Division of Mammals, MRC-108
Washington, DC 20560
Phone: (202) 357-1920
Fax: (202) 786-2979
Email: wilson.don@nmnh.si.edu

Mike Wunder
Colorado Natural Heritage Program
254 General Services Building
Colorado State University
Fort Collins, CO 80523
Phone: (970) 491-2841
Fax: (970) 491-3349
Email: mbw@lamar.colostate.edu